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IMPLEMENTATION OF THE NAIROBI PROGRAMME OF ACTION FOR THE DEVELOPMENT AND UTILIZATION OF NEW AND RENEWABLE SOURCES OF ENERGY: CONTRIBUTION TO THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT

Solar energy: a strategy in support of environment and development

Report of the Secretary-General**

1. During its fifth session, held at United Nations Headquarters from 26 March to 4 April 1990, the Committee on the Development and Utilization of New and Renewable Sources of Energy made a recommendation endorsed in General Assembly resolution 45/208 of 21 December 1990. In that resolution, the General Assembly requested the Secretary-General to prepare a comprehensive and analytical study on new and renewable sources of energy with a view to providing a significant contribution to the United Nations Conference on Environment and Development, through the Preparatory Committee for the Conference, to enable it to consider appropriate action, including funding and technology transfer, within its area of competence and within existing financial resources, not excluding voluntary contributions, and also requested the Secretary-General to submit a report to the Preparatory Committee at its

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* A/AC.218/1992/1.

** The present report is to be submitted also to the Preparatory Committee for the United Nations Conference on Environment and Development (UNCED) at its fourth session.

fourth session and to the Committee on the Development and Utilization of New and Renewable Sources of Energy at its sixth session.

2. In view of the importance of these requests, the Director-General for Development and International Economic Cooperation established a high-level group of experts to be known as the United Nations Solar Energy Group on Environment and Development (UNSEGED) and entrusted that Group with the task of preparing a first quality report. The Group held six meetings before adopting its final report in Oslo (17 and 18 October 1991). That report is reproduced in annex I of the present report; annex II comprises a list of members of UNSEGED, United Nations participants, and observers.

Annex I

SOLAR ENERGY: A STRATEGY IN SUPPORT OF ENVIRONMENT AND DEVELOPMENT

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I. SUMMARY AND RECOMMENDATIONS OF THE UNITED NATIONS SOLAR ENERGY GROUP ON ENVIRONMENT AND DEVELOPMENT 1/ (UNSEGED)

A. Impetus

1. Development, economic growth and population increase lead to ever-greater energy service requirements. These growing requirements must be met in a sustainable way. Current patterns of energy production, transportation and use do not meet these requirements and do not lead to a sustainable world.

2. Energy production, transformation, transportation and utilization account for at least as many global or regional man-made environmental problems as all other human activities combined and also cause major national and local environmental damage.

3. Energy issues are central, therefore, to discussions of the environment and development.

4. The energy sector represents a large fraction of national and international economies. Globally, energy accounts for 25-30 per cent of present investments in development and economic growth. Energy sector investments are therefore important determinants of the direction of societal development.

5. Maintaining current patterns of fossil fuel use will cause unprecedented rates of global surface temperature increase, resulting in the disruption of the Earth's climate. The scientists on the Intergovernmental Panel on Climate Change concluded that, in order to stabilize atmospheric concentrations of carbon dioxide (CO_2) at today's levels, an immediate reduction of anthropogenic CO_2 emissions by more than 60 per cent would be necessary. Fossil fuel use is the main source of anthropogenic CO_2 emissions. Such a reduction implies, therefore, a profound change in the commercial energy system, of which about 88 per cent is currently supplied with fossil fuels.

6. Energy strategies should be used as instruments for sustainable development and environment preservation. Increasing the share of renewable energy sources in the total world energy supply and improving energy efficiency will be the essential elements of any strategy for achieving sustainable development and environment preservation. Public concern about nuclear power has increased and investments have slowed considerably, reducing the potential role nuclear power might play in such a strategy. The present report deals solely with renewable energy sources. The term solar energy is hereinafter used broadly to mean all renewable energy sources.

B. Background on renewable energy sources in the United Nations system

7. Concern in the 1970s over uncertainties of fuel supply and future depletion of fossil fuels led to increased interest within the international

community in expanding the utilization of new and renewable energy sources. The Nairobi Programme of Action for the Development and Utilization of New and Renewable Sources of Energy (NPA) 2/ was established in 1981 as a comprehensive international effort for developing and utilizing new and renewable energy sources.

8. The decade following adoption of the Nairobi Programme of Action was essentially lost, not because of lack of technical progress or failure of individual projects, but because the political resolve expressed in the Nairobi Programme of Action was not supported by: agreed-upon targets quantifying the objectives of the Nairobi Programme of Action; correspondingly, financial commitments; and adequate institutional support, especially in the industrialized countries.

9. The absence of those fundamental structure-forming mechanisms left room for the continuation of national policies that inhibited the promotion of renewable energy sources. Such policies included:

(a) Lack of support, policy development and legislation for broad dissemination of new technologies;

(b) Small and declining support for research and development (R&D) on renewable energy sources at the national level in most Organisation for Economic Cooperation and Development (OECD) countries (after a build-up period, expenditures of International Energy Agency [IEA] Governments on energy research and development were reduced by more than 70 per cent between 1980 and 1987. Only 7 per cent of the 1990 expenditures was directed to renewable energy sources);

(c) Exclusion of external costs and non-monetary benefits in economic evaluations of energy technologies and systems;

(d) Large subsidies provided in many countries for conventional energy sources. Some of these subsidies were made directly in the form of large State-run development programmes or tax relief while others were indirect and manifest in ignored environmental costs and government responsibility, inter alia, for insurance and waste disposal.

10. The government signals reflected in (a) through (d), along with new discoveries of fossil fuel resources, changing economic conditions and falling oil prices, led to small and declining private investments in renewable energy.

C. Renewable energy sources

11. The flow of renewable energy to the Earth's land surface is thousands of times greater than mankind's present rate of total energy use. Utilizing only a small fraction of this resource would provide humanity with an alternative and environmentally sound path towards meeting future energy needs.

12. The present total commercial world energy supply is about eight gigatons of oil equivalent (Gtoe) per year. Renewable energy sources contribute about 7 per cent, most of which is large-scale hydropower, of that supply. Including non-commercial energy sources, renewable energy sources contribute 14-20 per cent of the total primary energy supply.

D. Technologies

13. Renewable energy sources can be used to produce a variety of energy carriers, such as liquid fuels and electricity, which can be utilized within the existing transmission, distribution and end-use infrastructure in both industrialized and developing countries.

14. Several technologies for utilizing renewable energy sources are mature and economically competitive, and they are diffusing through the market even under present conditions. Electricity generation in biomass-fuelled plants in the United States of America increased from about 250 to 9,000 megawatts (MW) during the 1980s. Solar thermal plants of 350 MW of installed capacity are selling electricity to the grid at competitive prices in California and more 350 MW plants are being built. World-wide geothermal power capacity increased from 2,000 MW in 1980 to 5,830 MW in 1990. Wind farms provide 1,900 MW of electricity to the grid in locations such as California, Denmark, India and the Netherlands and, after a dramatic cost reduction in the 1980s, are now economically competitive with coal-based plants on sites with favourable wind regimes. Ethanol from biomass is used in Brazil as an automotive fuel in approximately 4 million automobiles and is also used as an octane enhancer. Current production volumes exceed 200,000 barrels per day. About 110,000 small wind generators and 1,600 wind pumps are operating in China. Several million household anaerobic digesters are operating in China and India and several million household solar water heaters are in use in those countries. Passive solar technologies for heating and cooling, if introduced at the design stage, are paid back in three to five years.

15. Some renewable energy technologies and energy carriers show great promise. The two most important examples are photovoltaics and new advanced uses of biomass for gasification/power generation and liquid fuel production. Doubling its size about every four years, the photovoltaics market has grown steadily to present sales of 50 MW of power per year. Photovoltaic electricity-generating costs have decreased markedly, making some applications economically feasible, and with adequate research, development and demonstration (RD&D) efforts are expected to be competitive with central-station generation after the year 2000. Many advanced biomass production and conversion technologies are being developed. Large-scale RD&D efforts would greatly improve and accelerate the economic potentials of such technologies.

16. A renewable energy system will, by nature, include a wide variety of technologies that harness a range of energy forms. Such a system will be decentralized, with components of different scales designed to meet local and regional needs. The energy flows into the system will vary spatially and

fluctuate over time. The supply technologies used in a renewable energy system and the end-use technologies used to meet the demand for energy services must therefore be well integrated. The technologies needed for providing such integration are already available.

E. Potentials

17. Taking into account the availability of cost-effective technologies and levels of energy end-use in different climate zones, the near-term (1990-2000) global economic potential to supply energy based on renewable sources is about 3.3 Gtoe per year, that is, 2.5 times the 1985 contribution. The major quantitative increments of the near-term renewable potential are expected to derive from the sustainable use of biomass and large-scale hydropower. The rate at which emerging technologies are developing indicates a minimum potential contribution of 5 Gtoe per year in 2020, that is, an increase of 3.5 Gtoe over the present contribution. Emerging energy technologies, such as photovoltaics and new biomass technologies, can come to play a dominant role in the early twenty-first century. In the long term, the utilization of renewable energy sources is not likely to be constrained by the availability of resources or cost-effective technologies. At present, political and administrative decisions are its primary constraints. The opportunity now exists to start the transition to an energy system for a sustainable world.

F. Advantages

18. Replacing conventional energy sources with renewable ones would reduce many environmental impacts caused by the current energy system, including greenhouse gas emissions, land degradation, air and water pollution, acid precipitation and emissions of radioactive substances.

19. The scale of facilities for manufacturing devices for utilizing renewable energy sources can be comparatively modest. With access to some of these technologies, developing nations will be able to reduce foreign capital outlays by developing endogenous manufacturing capabilities. Such industries can contribute to local economic growth. Producing alternative fuels can also reduce foreign capital expenditures in many countries.

20. Utilizing renewable energy sources can provide training and employment opportunities that would otherwise not be available, thereby supporting development based on self-reliance.

21. Locally available primary energy resources are, in essence, free from control outside national boundaries. They therefore provide a secure, independent energy supply, an important element of sustainable and autonomous development.

22. The time period required from planning through implementation of renewable energy supply projects is often much shorter than that of

conventional, large-scale supply projects. This characteristic offers flexibility and reduces investment and (as a consequence) delivered-energy costs.

23. Most renewable energy technologies are designed in modules, simplifying installation and maintenance and offering the added advantage of flexibility in increasing supply capacity.

24. The opportunity exists for establishing rational and efficient energy systems based on technologies that utilize renewable energy sources. For environment- and development-related reasons, establishing such systems must be a goal for the first part of the next century.

G. Constraints on the rate of expansion

25. The technological limits to the diffusion of existing competitive technologies for utilizing renewable energy sources derive mainly from the time needed to increase global capacities for producing them.

26. Because financial resources are scarce, the setting of priorities for energy-sector investments will determine the penetration rate of technologies that utilize renewable energy sources. A transition to a global energy system based on renewable energy sources will not take place unless the share of energy-sector investments devoted to renewable energy technologies is greatly increased.

27. Current practices for distributing development aid favour large-scale projects. Project orientation must be replaced by programme orientation in order to make funds available for small-scale decentralized technologies that utilize renewable energy sources.

28. Global renewable energy resources are more than sufficient for meeting the demand for energy services. However, conflicting demands on natural resources, such as food- versus energy-production-related demands on arable land, must be addressed in evaluating the accessible potential for utilizing biomass resources within individual countries.

29. Within the limitations posed by technological, financial and natural resources, the extent to which renewable energy sources contributes to the future world energy supply will depend on energy-policy decisions made by Governments and on coordinated international cooperation.

H. Recommendations

30. Seizing the opportunity to develop a sustainable global energy system based on renewable energy sources will require fundamental structural, economic and institutional changes in industrialized and developing countries. None of these changes can be achieved without unyielding political will, international cooperation, and active public and private involvement.

31. Adopting a long-term approach is vital for the development of the physical as well as the policy and institutional infrastructure needed for utilizing renewable energy sources.

32. Implementing such an approach will require both transitional and foundation-building policies. Towards those ends, we make the following recommendations.

33. At the national level, it is essential to formulate integrated energy policies and programmes compatible with sustainable development and to promote increased investments in renewable energy supplies. We therefore recommend that Governments:

(a) Adopt and implement an integrated national action programme on the development and utilization of renewable energy sources within the framework of strategies and policies for the transition to energy systems compatible with sustainable development;

(b) Establish targets for contributions of the different renewable energy sources to their energy supply, commensurate with the time-frames of technical feasibility outlined above. Such targets should be linked to environmental as well as social and developmental objectives;

(c) Establish and strengthen institutional arrangements that facilitate the implementation of the national programme, including policies and programmes for achieving the set targets. Appropriate governmental institutions should be given the mandate of promoting the utilization of renewable energy sources through education, training and information programmes; energy/environment planning and policy coordination; and research, development and demonstration;

(d) Enlarge markets for renewable energy applications by adopting new regulatory and fiscal legislation that, inter alia, ensures that all costs and benefits (environmental and social, among others) are included in the market price and in economic comparisons of public and private energy-sector investment options, and public procurement policies;

(e) Increase public funding of research into the utilization of renewable energy sources by a factor of at least three, on average, within five years;

(f) Ensure that the share of public energy investments devoted to promoting research, development, demonstrations and training related to renewable energy sources is commensurate with the potential of those sources to meet national energy needs and global responsibilities;

(g) Ensure that renewable energy sources are not discriminated against in domestic energy markets by the subsidizing of other energy sources directly or indirectly, and that small or independently owned producers are not discriminated against by utilities or denied access to transmission and distribution systems;

(h) Establish and implement procedures for recording statistical data on renewable energy applications in their country. Such data should be collected in a harmonized form, so that they can be useful at the international level;

(i) Report on their national programmes of action for promoting renewable energy sources in order to facilitate an international dialogue (see paras. 34 (a) and 35).

34. At the international level, arrangements must be made, in close collaboration with national and international institutions and non-governmental organizations, to strengthen international cooperation for promoting the utilization of renewable energy sources. Those arrangements should intensify research, development and demonstration in the area of renewable energy technology, stimulate broad dissemination and application of available renewable energy technologies and provide for exchange of information and manpower training for use of such technologies. Towards these ends, it is necessary to:

(a) Promote and support policy planning, inter alia, by organizing a dialogue with each nation based on national renewable energy policy and programme reports (see para. 33 (i));

(b) Promote rapid implementation of systems based on renewable energy sources, especially in industrial countries because of their dominant use of fossil fuels;

(c) Restructure energy-sector expenditures so that renewable energy sources and technologies for their utilization, together with energy-efficiency improvements, are given first priority;

(d) Promote increased funding, inter alia, from new and additional financial resources, in support of the implementation of national action programmes on renewable energy sources, in particular in the developing countries;

(e) Promote rapid and effective transfer of environmentally sound technologies for utilizing renewable energy sources among countries in general and (on favourable and concessional terms) to developing countries in particular. In this regard, action should be taken to (i) adapt currently available technologies to local conditions, (ii) promote the build-up of the endogenous expertise and infrastructure needed to enable the implementation of renewable energy programmes, and (iii) promote local production of technologies to enhance national self-reliance;

(f) Prepare and disseminate studies on new technological developments, techniques and strategies for identifying, locating and evaluating new and renewable energy sources;

(g) Allocate, in the coming years, a minimum of 20 per cent of all funding aid from bilateral, multilateral and international agencies devoted to

the energy sector to viable renewable energy projects, in addition to large-scale hydropower. The same arrangement should apply to grants and loans from international development banks, and this percentage should increase over time;

(h) Increase capacity-building efforts, particularly in developing countries, to ensure increased development and implementation of renewable energy programmes;

(i) Coordinate international activities aimed at promoting the utilization of renewable energy sources;

(j) Promote research, development and demonstration programmes in developing countries for technologies that utilize renewable energy sources;

(k) Coordinate the exchange of information and experience on research, development and applications of renewable energy technologies;

(l) Gather statistics from individual countries on, and perform evaluations of applications of, renewable energy sources;

(m) Implement the proposal by the Colloquium of High-level Experts on New and Renewable Sources of Energy (Castel Gandolfo, Italy, 5-7 October 1987) to establish a network of international centres in new and renewable sources of energy.

35. We believe that a strong international institutional arrangement is needed to carry out the above tasks and give renewable energy necessary visibility and weight in such areas of relevant international negotiations as the framework convention on climate change. The creation of an international renewable energy agency responsible for promoting renewable energy sources is therefore recommended. This agency should be responsible for the activities enumerated above in paragraph 34 (a), (b), (d), (e), (f), (h), (i), (j), (k), (l) and (m) and should act as a network focal point for national and international institutions, stimulating and supporting two-way communication between them.

II. THE NAIROBI PROGRAMME OF ACTION FOR THE DEVELOPMENT AND UTILIZATION OF NEW AND RENEWABLE SOURCES OF ENERGY: LESSONS LEARNED

A. The Nairobi Programme of Action for the Development and Utilization of New and Renewable Sources of Energy: objectives and rationale

1. Energy transition

36. The Nairobi Programme of Action for the Development and Utilization of New and Renewable Sources of Energy (NPA) was adopted by consensus at the

United Nations Conference on New and Renewable Sources of Energy, held on 10-21 August 1981 in Nairobi. At that time, according to the general perception the world was facing an energy transition from an international economy based primarily on hydrocarbons (fossil fuels) to one based increasingly on a more diversified resource base. This perception stemmed from the recognition a few years earlier that fossil fuels were depletable. The international economy could not, therefore, continue to rely predominantly on those fuels. The situation was compounded by their inefficient and wasteful use, which had reached unsustainable levels.

37. There was no question whether an energy transition would take place. The Nairobi Programme of Action, conceived as a major undertaking of international cooperation for supporting and assisting action at the national level, was intended to help ensure that the transition would take place in a manner that, consistent with the needs and options of individual countries, was socially equitable, economically and technically viable, and environmentally sustainable.

38. The Nairobi Programme of Action conveyed a sense of urgency for the development and utilization of new and renewable sources of energy (NRSE) 3/ that was consistent with the need to keep up with the pace of the energy transition. The emphasis of the Nairobi Programme of Action was on the contribution of new and renewable sources of energy to meeting the energy needs of the developing countries.

39. In developing countries, new and renewable sources of energy had the double advantage of representing an option both for developing indigenous resources and for contributing to the meeting of energy needs in rural areas with decentralized energy supplies. At the time of the United Nations Conference on New and Renewable Sources of Energy, prevailing as well as projected future energy prices represented another incentive for undertaking major efforts to develop new and renewable sources of energy in developing countries. Such efforts were seen as a means of reducing the balance-of-payments burden caused by importing energy.

2. Structure of the Nairobi Programme of Action

40. The Nairobi Programme of Action provides a comprehensive description of specific technical measures for developing and utilizing each of the new and renewable sources of energy in five broad policy areas: energy assessment and planning; research, development and demonstration; transfer, adaptation and application of mature technologies; information flows; and education and training. Furthermore, the Nairobi Programme of Action identifies a number of areas for priority action, covering all five policy areas, where action is needed on an urgent basis.

41. The Nairobi Programme of Action calls for both financial and technical actions for the development and utilization of new and renewable sources of energy. Specific measures contained in the Nairobi Programme of Action

concentrate on supporting actions and pre-investment activities aimed at providing a strong impetus to the development and utilization of new and renewable sources of energy. (Supporting actions include energy assessment and planning; establishment and strengthening of relevant national institutional infrastructure; research, development and demonstration; data collection; and training and education. Pre-investment activities include feasibility studies, and design and engineering.) At the time of the Conference, it was perceived that development of new and renewable sources of energy at the commercial level - even though it required significant capital outlays - would attract funding from already-existing international and other financial institutions.

3. Impact of energy prices

42. Falling energy prices in the years that followed the Conference led many to believe that the Nairobi Programme of Action had lost at least its sense of urgency, if not its very purpose. In addition, short-term gluts in the oil market were instrumental in bringing about a collective loss of sight among decision makers considering energy options and policies of the depletable nature of fossil fuels. As a result, there was a definite loss of interest by some Governments in supporting the Nairobi Programme of Action. The loss of interest resulted in a loss of momentum in the Programme's implementation, in spite of repeated warnings by the United Nations and many Governments that the need to develop new and renewable sources of energy should be seen from a long-term perspective.

43. In addition, implementation of the Nairobi Programme of Action was adversely affected by such developments as the general de-emphasis on large-scale demonstration projects in industrialized countries and the discovery, as a result of oil exploration, of natural gas resources in some developing countries.

B. Assessing the implementation of the Nairobi Programme of Action

1. Basis for an assessment

44. In so far as the Nairobi Programme of Action is a complex effort involving numerous energy sources, a wide range of specific technical and financial measures, decentralized implementation, and participation of a number of actors, both national and international, public and private, its implementation must be assessed from a variety of viewpoints. In particular, a comprehensive assessment should examine:

(a) The changing share of new and renewable sources of energy in energy supply on a global basis. The rate of change of that share should be measured, including and excluding large-scale hydropower, whose relative weight in new and renewable sources of energy is extremely high;

(b) The contribution of new and renewable sources of energy at the local level, since their significance would have to be judged in terms of widespread applications, such as energy services, in particular for small and remote communities, rather than massive ones;

(c) The progress or lack thereof in each of the various action areas called for in the Nairobi Programme of Action, for example, specific measures, areas for priority action, and institutional and financial arrangements;

(d) Changes in the rate of progress over time, as compared with those in the price of energy;

(e) Resources allocated to new and renewable sources of energy programmes within the budgets of the major institutions involved: national institutions, entities of the United Nations system, international financial institutions, other international institutions, and bilateral cooperation organizations.

2. Concrete goal setting

45. During the Conference it was agreed that implementation of the Nairobi Programme of Action for the Development and Utilization of New and Rewewable Sources of Energy required additional and adequate financial resources, in other words, those resources were not to be provided at the expense of other programmes, existing or planned, of international cooperation. It was not possible, however, for the Conference to reach an agreement on the financial commitment of the international community to the Nairobi Programme of Action, in terms, for example, of a financial target or a mechanism for annual or multi-year contribution pledges. The Nairobi Programme of Action contains only a description of avenues for mobilizing financial resources, with emphasis on consultative meetings.

46. In addition, the magnitude of the financial needs was not stipulated in the Nairobi Programme of Action. Thus, no common yardstick was provided for measuring progress. However, two documents prepared in 1982 provide a reference for making an assessment, at least in general terms.

47. A joint study by the World Bank and the United Nations Development Programme 4/ addressed the problem of estimating the financial resources needed for the supporting actions and pre-investment activities related to implementation of the Nairobi Programme of Action for the 1980s, on the basis of a conservative assessment of projects and programmes that could be carried out in the developing countries.

48. In the study, national financial requirements for each of the new and renewable sources of energy were derived on the basis of country data, where available, and estimates, where detailed data were lacking. The resource base as well as national plans and programmes according to national priorities were a basic input for the study, and the national calculations were aggregated to

estimate global financial requirements. It was assumed that energy demand would grow in developing countries at a rate of 5-6 per cent per annum. Prices of liquid fossils would tend to rise in the long term from their 1982 levels, despite the short-run prospects of a decline in real terms. Developing countries were expected to have a firm commitment to developing their indigenous new and renewable sources of energy. Supporting actions and pre-investment activities would be concentrated in areas where development of those energy sources was perceived to be both technically and economically feasible.

49. The results of the study indicated that implementation of such supporting actions and pre-investment activities would require $US 3.6 billion and $US 10.6 billion respectively, that is, a total of some $US 14 billion for the period 1982-1990. On an annual basis, financial requirements were estimated at $US 1 billion for the period 1982-1986 and $US 2 billion for the period 1986-1990. (Note: All monetary values in the present report are given in current United States dollars, except where otherwise noted.)

50. Supporting actions and pre-investment activities normally represent 5-10 per cent of the total financial resources needed for the development of new and renewable sources of energy at the commercial level. The total financial requirement for implementing the Nairobi Programme of Action was estimated, therefore, to be between $140 billion and $280 billion ($15 billion-$30 billion annually).

51. A report prepared by the Administrative Committee on Coordination in 1982 5/ contained a number of projects and programmes aimed at providing a framework for action by the United Nations system in implementing the Nairobi Programme of Action. It represented the collective judgement of the interested entities within the United Nations system on the activities necessary for the immediate launching of the Programme.

3. Institutional arrangements

52. Institutional arrangements at the United Nations level for implementing the Nairobi Programme of Action were completed consequential to General Assembly resolution 37/250 of 21 December 1982. They included the establishment of an open-ended intergovernmental committee and secretariat arrangements. During the process of preparations for the United Nations Conference on New and Renewable Sources of Energy the idea of creating an agency for promoting new and renewable sources of energy was considered but not taken further.

53. The intergovernmental Committee on the Development and Utilization of New and Renewable Sources of Energy meets every two years, in even years, and has a wide range of responsibilities for implementing the Nairobi Programme of Action, including monitoring and follow-up of implementation and of activities related to new and renewable sources of energy of the entities within the United Nations system; recommendation of policy guidelines to such entities;

formulation and recommendation of action-oriented plans and programmes; promotion of the mobilization of financial resources; and recommendation of guidelines to the financial organs within the United Nations system. The Committee launched its activities at its first session, held in 1983. Since then, four additional sessions have been held, in 1984, 1986, 1988 and 1990.

54. The first session was devoted to finalizing and adopting the various arrangements needed for implementing the Nairobi Programme of Action, whereas the four subsequent sessions were aimed at adopting the necessary decisions to ensure an effective contribution of the United Nations system to the implementation of the Nairobi Programme of Action and, in a broader sense, to maintain interest and support within the international community for promoting new and renewable sources of energy.

55. A number of criticisms have been made regarding the effectiveness of the Committee's work, in particular regarding the lack of in-depth technical discussions and the limited participation of member countries in the meetings. At each of its sessions, however, the Committee has executed its responsibilities with regard to the monitoring and follow-up of the implementation of the Nairobi Programme of Action.

56. At its third session (in 1986), the Committee decided to concentrate on a limited number of specific subjects for deliberation. This initiative proved to be successful and has provided a focus for the inter-sessional work of the secretariat and allowed for more substantive discussions during Committee meetings.

57. The secretariat arrangements include a special coordinator for new and renewable sources of energy in the office of the Director-General for Development and International Economic Cooperation of the United Nations Secretariat and a secretariat unit. The secretariat unit was established in 1982 as a small separate unit in the Department of International Economic and Social Affairs of the United Nations Secretariat and is responsible for providing secretarial support to the meetings as well as for gathering and disseminating information regarding new and renewable sources of energy in general and the Nairobi Programme of Action in particular. In 1989 the unit was merged with the Department of International Economic and Social Affairs unit in charge of conventional energy resources.

58. Experience has thus far shown that the secretariat arrangements have been inadequate and have impeded the provision of the full range of secretarial services and support required by the intergovernmental Committee to carry out its mandate.

4. Inter-agency coordination

59. Because a number of entities within the United Nations system had been undertaking activities related to various new and renewable sources of energy, it was agreed at the Conference that the Nairobi Programme of Action would be

implemented in a decentralized manner. This arrangement called for strong coordination of activities within the United Nations system in order to avoid duplication of work and inefficient use of resources. The Director-General for Development and International Economic Cooperation was entrusted with the task of ensuring that such coordination took place. Although exchange of information between the specialized agencies has improved slightly, experience thus far shows that inter-agency coordination has been completely inadequate.

60. Timely availability of accurate information is essential for the successful coordination of activities within and outside the United Nations system. To that end, Governments were requested to designate focal points for new and renewable sources of energy at the national level. Entities within the United Nations system were also requested to designate focal points for those energy sources.

61. So far, a combined total of 120 countries and United Nations entities involved in activities concerning new and renewable sources of energy have designated their focal points for those energy sources. Even though there has been no formal assessment of the role and effectiveness of such focal points in the implementation of the Nairobi Programme of Action, there is general concern that the flow of information needs to be improved.

5. Mobilizing financial resources

62. As acknowledged at the Conference, implementing the Nairobi Programme of Action requires the mobilization of additional and adequate financial resources. A clear-cut assessment of progress made in this regard would require a common yardstick for measuring progress as well as a consistent way of reporting on mobilized resources.

63. A report of the Secretary-General submitted to the Committee on the Utilization and Development of New and Renewable Sources of Energy at its fourth session, held from 28 March to 8 April 1988, 6/ stated that resources mobilized for utilizing new and renewable sources of energy, as well as for energy planning and energy conservation, in developing countries totalled about $35.9 billion for the period 1980-1987. It should be noted, however, that 74 per cent of this amount was allocated to large-scale hydropower and that only $9.4 billion were mobilized for all other new and renewable sources of energy. A meaningful assessment must therefore consider large-scale hydropower and other new and renewable sources of energy separately.

64. As indicated in the report, data were compiled on the basis of information provided to the United Nations Secretariat. There appeared to be an understatement of the efforts made by the developing countries themselves, that is, by the national sources of financing. National efforts represented the largest single source of financing for developing and utilizing new and renewable sources of energy when large-scale hydropower was included and the second largest single source after the United Nations system when large-scale hydropower was excluded. A breakdown by source of financing is given in table 1.

Table 1. Funding sources for promoting and utilizing new and renewable sources of energy in developing countries, 1980-1987

Source of financing	All new and renewable sources of energy excluding large-scale hydropower		Large-scale hydropower	
	Millions of US dollars	Percentage	Millions of US dollars	Percentage
National	2 300	25	7 000	27
Bilateral	2 200	23	4 400	17
Intergovernmental	1 200	13	4 800	18
United Nations system	3 500	37	5 300	20
Private	a/	a/	2 500	9
Other	200	2	2 500	9
Total	9 400	100	26 500	100

Source: Mobilization of financial resources and inter-agency coordination for the development and utilization of new and renewable sources of energy: report of the Secretary-General (A/AC.218/16).

a/ Amount negligible.

65. When considering contributions by energy source, a number of activities, such as energy planning or conservation that encompasses conventional energy sources as well as new and renewable sources of energy, cannot be allocated to a specific source. Bearing this in mind and considering large-scale hydropower separately, table 2 provides a breakdown of total developing country financing by energy source.

66. Global mobilization of financial resources for new and renewable sources of energy, including large-scale hydropower, averaged $4.5 billion per annum over the period 1980-1987. This represents only 15 to 30 per cent of the $15 billion to $30 billion per annum identified as necessary in the United Nations Development Programme-World Bank joint study.

Table 2. Main areas of activity in promoting the utilization of new and renewable sources of energy in developing countries, 1980-1987

Area of activity	Allocation (millions of US dollars)	Percentage
Fuelwood and charcoal	1 900	20
General new and renewable sources of energy	1 800	19
Conservation (conventional and new and renewable sources of energy)	1 400	15
Geothermal	1 200	13
Energy planning	1 200	13
Solar	600	6
Small-scale hydropower	600	6
Other	700	8
Total	9 400	100

Source: Mobilization of financial resources and inter-agency coordination for the development and utilization of new and renewable sources of energy: report of the Secretary-General (A/AC.218/16).

67. The 1990 report prepared by the Secretary-General in response to requests made by the Committee on the Development and Utilization of New and Renewable Sources of Energy at its fourth session 7/ provides data only on financial resources mobilized by the United Nations system. Total United Nations resources committed for the period 1980-1989 amounted to $13.4 billion, the largest part of which (67 per cent) was allocated to conventional large-scale hydropower projects.

68. Although that figure seems to compare favourably with the one submitted in the 1988 report, there has been a continuous decline in resources mobilized by the United Nations system since 1987, when commitments peaked at $1.9 billion. In 1988, the figure was reduced to under $1.5 billion and in 1989 it was further reduced to under $1.4 billion.

69. Both the 1988 and 1990 reports clearly indicate an unfavourable and undesirable trend in the mobilization of financial resources for developing and utilizing new and renewable sources of energy. This trend was consistent with the loss of the sense of urgency in implementing the Nairobi Programme of Action that was experienced in the years following the Conference.

70. The reduced effort was not limited to cooperation at the international level: significant reductions of effort occurred at the national level in industrialized countries. One indication of this was the steady decline in government research, development and demonstration (RD&D) budgets for new and renewable sources of energy in industrialized countries since the adoption of the Nairobi Programme of Action, as illustrated in table 3, derived from a report on energy policies of International Energy Agency (IEA) countries. 8/

Table 3. Research, development and demonstration (RD&D) budgets for energy of International Energy Agency (IEA) Governments

Year	Total energy sector (millions of 1990 dollars)	Allocation for new and renewable sources of energy	
		Millions of 1990 dollars	Percentage of total
1979	10 760	1 430	13
1980	11 610	1 670	14
1981	11 810	1 660	14
1982	10 730	1 130	11
1983	9 770	980	10
1984	9 430	930	10
1985	9 120	740	8
1986	8 200	580	7
1987	6 830	540	8
1988	7 270	540	7
1989	7 550	500	7
1990	7 200	490	7

Source: Organisation for Economic Cooperation and Development (OECD), Energy Policies of IEA Countries (Paris, 1991).

Note: The International Energy Agency includes solar (heating, thermal, photovoltaic, among others), wind, biomass, ocean and geothermal energy sources in these data. The figures for 1979 through 1987 do not include expenditures on electric power transmission, energy storage and other items as is the case for the data for 1988 through 1990. The new and renewable sources of energy share of total expenditures is therefore probably overestimated for the period 1979-1987.

71. The Energy Account of the United Nations Development Programme (UNDP) has been another major casualty of the declining trend in resource mobilization. The Energy Account was considered to be one of the major mechanisms for mobilizing financial resources for developing and utilizing new and renewable sources of energy. At its thirty-fifth session (June/July 1988), the UNDP Governing Council decided to close the Energy Office, while the Energy Account would be maintained as a sub-account of the United Nations Fund for Science and Technology for Development. This decision was made as a result of the lack of resources channelled through the Energy Account.

72. In addition to the overall trend towards reduced funding, a number of shortcomings in the mechanisms for mobilizing financial resources may have contributed to the lack of success in fund-raising. Consultative meetings provide a good illustration in this regard.

73. Consultative meetings were presented as a useful and effective means of mobilizing financial resources for developing new and renewable sources of energy, since they provided a forum for consideration by donors and recipients of a limited number of concrete projects. The first consultative meetings were organized in 1982. Experience thus far leads to the following conclusions:

(a) There has been no common understanding of the purpose of consultative meetings. Some donors perceive them as a forum for holding general discussions on projects unrelated to financial commitments to support those consultative meetings. Recipients expect the meetings to result in actual mobilization of resources. In other words, donors consider such meetings the beginning of a process, while recipients consider them to be conclusive;

(b) Attempts to measure the effectiveness of the consultative meetings in terms of mobilization of resources for the projects presented at such meetings have been unsuccessful. No relationship between the discussions held at the consultative meetings and actual contributions has been clearly established and assessments undertaken by the United Nations Secretariat are inconclusive in this regard;

(c) The difficulties in organizing consultative meetings and the small number that have been held indicate that such meetings are ineffective as a mechanism for mobilizing financial resources and should not be relied upon as the primary mechanism for mobilizing those resources.

6. Concrete projects and programmes

74. The Secretary-General has reported on the status of the implementation of projects and programmes submitted by the United Nations system since 1982. 9/ 10/ The overall conclusion of the reports is that the rate of progress has varied widely both for the different projects and programmes and for the various United Nations entities involved. While some projects and programmes have been fully implemented, others remain to be completed.

75. As indicated in the reports, the main cause of non-completion of projects has been lack of financial resources. This is again an indication of the loss of interest in supporting new and renewable sources of energy activities that stemmed from falling energy prices in the 1980s.

7. Share of new and renewable sources of energy in global energy supply

76. At the time of the Conference, new and renewable sources of energy accounted for 13 per cent of the world energy supply. In 1985, the share of new and renewable sources of energy remained at approximately the same level (14 per cent). Estimates of current global renewable energy use are in the range of 14-20 per cent of the total primary energy supply. 11/ The bulk of the supply of new and renewable sources of energy comes from three sources: large-scale hydropower, fuelwood and charcoal. These sources accounted for over 94 per cent of total production of new and renewable sources of energy in 1981 and 91 per cent in 1985. 12/

77. According to United Nations statistics, new and renewable sources of energy in the developing countries accounted for 29 per cent of total energy consumption in 1981 and 28 per cent in 1985. A breakdown by regions indicates that in 1981 new and renewable sources of energy accounted for 57 per cent of total energy consumption in Africa, 34 per cent in Latin America and the Caribbean, and 23 per cent in Asia and the Pacific. The figures for 1985 were 56 per cent (Africa), 38 per cent (Latin America and the Caribbean) and 21 per cent (Asia and the Pacific). 13/

78. Those figures illustrate the lack of increase in the share of new and renewable sources of energy in global energy production and consumption in the first four years after adoption of the Nairobi Programme of Action.

C. Lessons learned from the implementation of the Nairobi Programme of Action

79. Since the adoption of the Nairobi Programme of Action, there has been a big difference in the emphasis attached to new and renewable sources of energy in industrialized and developing countries. Such a difference is reflected in institutions, policies and efforts devoted to developing and utilizing those sources of energy.

80. In response to the call for concerted action made at the United Nations Conference on New and Renewable Sources of Energy, all countries, developing and industrialized, set up institutions for developing and utilizing new and renewable sources of energy by adopting the Nairobi Programme of Action. In developing countries, the establishment of institutions and focal points for energy planning and for planning for development and utilization of new and renewable sources of energy was, in particular, a major achievement. Developing countries in general tried to pursue the policies they had

established regarding those energy sources. However, while in developing countries such institutions have generally been maintained and strengthened, in industrialized countries those institutions have been weakened through reduced budgets and even eliminated. Member countries of the Organisation for Economic Cooperation and Development (OECD), in general, reduced the role of new and renewable sources of energy in their energy policies in favour of developing other energy sources during the early 1980s. In recent years, however, environmental concerns have revived OECD interest in new and renewable sources of energy.

81. In most developing countries energy planning and policy-making for rural development remains weak and isolated from overall energy policy and planning efforts for the transportation, industrial and commercial sectors.

82. The rural sector is barely affected by competition from commercial sources of energy. Progress in that sector has been hindered by a lack of financial resources for initial energy investments. As a result, there has not been enough progress in the utilization of new and renewable sources of energy for integrated rural development.

83. As the mobilization of financial resources for implementing the Nairobi Programme of Action indicates, most developing countries have made sustained efforts commensurate with their own capabilities. Efforts to support the implementation of the Nairobi Programme of Action have been insufficient in most other countries.

84. Although there has been progress in some applications of new and renewable sources of energy, such as hydropower and geothermal energy, there is still a vast potential to be developed where demand for energy in general is not close to centralized energy sources. This is particularly true in many developing countries with limited industrial infrastructure.

D. Looking forward

85. Environmental concerns have brought a new perspective to the collective perception of the importance of the Nairobi Programme of Action, in particular since renewable energy sources are more environmentally benign than conventional ones. That could contribute to bringing about the political decisions needed to provide a new impetus for developing and utilizing new and renewable sources of energy. Success will be possible only if the issue is approached from a long-term perspective.

III. THE NEW RATIONALE FOR UTILIZING RENEWABLE ENERGY SOURCES

A. Introduction

86. Improving the quality of life of their citizens, inter alia, through economic growth and national autonomy, is a fundamental objective of all Governments and a particularly acute concern in developing countries.

Fulfilling that objective and the future needs of growing populations will inevitably require increased delivery of energy services. The quantity of primary energy required to deliver those services will depend on the level of energy efficiency of technologies for energy conversion, transmission, distribution and end-use. 14/

87. Current and projected energy production and use have major negative consequences for the global environment, sustainable development and security. Together these consequences provide a tremendous impetus for change, both in industrialized and developing countries. Most of the energy-related environmental, development and security problems (including climate change) are linked to fossil fuel use and non-sustainable use of biomass. Two major strategies exist for addressing these problems: (a) increasing energy efficiency in order to reduce the amount of primary energy consumed and (b) replacing fossil-fuel-based energy supply with expanded supplies of non-fossil sources. When formulating energy policy, special emphasis should be given to the interdependent relationships among the energy sector, economic growth, social development, the environment and security.

88. The global-warming challenge clearly illustrates the inseparability of the issues of development and environment. The energy system of the industrialized countries has led to a globally unsustainable environmental situation. Those countries must implement measures to limit the emissions of pollutants associated with fossil fuel use. Even a complete restructuring of the energy system in industrialized countries will be insufficient for addressing global warming unless sustainable development is addressed simultaneously. Developing countries must recognize the potential environmental hazards associated with increased energy use and integrate measures for preventing those hazards into their development plans. Although the environmental and developmental problems of industrialized and developing countries are different, the strategies for addressing those problems are applicable in both. The common objective is a sustainable society - locally, nationally, regionally and globally.

B. Environment

89. Our understanding of both the nature and magnitude of the environmental impacts of conventional energy systems has grown progressively over the past few decades, even if important areas of uncertainty still remain. Before the 1970s, the perceived hazards of energy use (a) were primarily local and regional in scope, (b) affected distinct populations and (c) were believed to be manageable. With urban air pollution and acid precipitation, the boundaries delineating the zones affected by such hazards expanded and confidence in our ability to both control and remedy their impacts diminished. The catastrophe at Chernobyl and the discovery of stratospheric ozone depletion brought about public and political realization that mankind's current actions pose threats of irreversible environmental degradation that respect no borders. Within this context, our perception of the threat of

global warming constitutes a yet further step in the progression of our conceptual understanding of the unsustainability of the energy system upon which we have become dependent.

90. Conventional methods of harnessing and using energy lead to a wide variety of environmental problems. Acid precipitation resulting from emissions of sulphur dioxide and oxides of nitrogen, primarily from burning fossil fuels, has already acidified tens of thousands of lakes and streams and been implicated in damage to a substantial part of the world's forests, especially in temperate regions. (In Europe alone, 42 per cent, or 60 million hectares, of forest is damaged.) 15/ Unsustainable utilization of biomass resources contributes to land degradation. These are just two examples of the many ongoing environmental problems that cannot be totally resolved with technical fixes or add-on measures such as stack gas scrubbers and catalytic converters. Adequately addressing any of these problems will require a restructuring of our system for utilizing energy and the formulation of new concepts regarding the relationships among quality of life, economic growth and social development within the framework of sustainability.

91. Of all the environmental challenges facing us today, global warming is the most pervasive. It demands the broadest scope of change by far. Such change can, however, offer simultaneous solutions to most of the other energy-related environmental problems.

92. In June 1990, the Intergovernmental Panel on Climate Change (IPCC), a group of 170 contributing scientists from 25 countries, sponsored by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), reached the consensus conclusion that increased atmospheric concentrations of the greenhouse gases resulting from human activities would enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface. 16/ In order to stabilize atmospheric concentrations at present-day levels, immediate reductions of (a) global man-made emissions of the long-lived greenhouse gases, namely, carbon dioxide (CO_2), nitrous oxide (N_2O) and the halocarbons (mostly chlorofluorocarbons) by more than 60 per cent and (b) methane emissions by 15-20 per cent would be necessary. 17/ However, even these reductions would not stabilize the climate.

93. Approximately half of all anthropogenic greenhouse gas emissions originate in production, transformation and utilization (including transportation) of fossil fuels. 18/ It may be possible to reduce fossil-fuel-related greenhouse gas emissions on the scale called for by the Intergovernmental Panel on Climate Change. In the alternative Accelerated Policies/High and Low Emissions scenarios developed by the Panel, emissions of CO_2 from fossil fuel use begin to decline immediately and continue to do so through the year 2100, and the emissions reductions necessary for stabilizing atmospheric concentrations of greenhouse gases are thereby exceeded. 19/ Those scenarios rely heavily on energy efficiency improvements aimed at reducing total energy demand and on increases in the utilization of renewable sources of energy.

C. Development

94. Fulfilling fundamental human needs and improving quality of life are the primary purposes of a development process. These objectives must be understood as the capacity to achieve social and economic growth in an environmentally sustainable manner based on a long-term perspective so that the interests of future generations are not compromised by decisions made today.

95. In the industrialized countries, economic growth has historically been achieved with little recognition of environmental problems. This, together with free access to natural resources, has resulted in misuse, overuse and degradation of the environment, with losses for humankind in general. Global sustainable development requires that industrialized countries radically change such practices (this has partially started) and that the developing countries find sustainable ways and means of achieving economic growth.

96. Sustainable economic and social growth requires husbanding non-renewable resources, maintaining renewable resource productivity and avoiding destructive and irreversible ecological effects. Moving towards a sound and sustainable system will require political, administrative and legislative decisions, which must lead to substantial changes in production and consumption patterns and an immediate reappraisal of development strategies.

97. Within this framework, the role of renewable energy sources in development is to provide indigenous, environmentally benign energy sources. Biomass, solar and wind energy constitute a widely distributed resource base that can be used as an instrument for development.

98. Utilizing renewable energy sources through the application of renewable energy technologies is especially valuable in rural and remote areas, which are home to roughly 3 billion people, or 60 per cent of the world's population. Residents of those areas do not have access to distribution networks to connect them to large-scale centralized energy-supply systems. Population increases exacerbate their poverty and push them to migrate to urban areas in search of sustenance. The resulting increases in demands placed on urban resources lead inevitably to increased use of energy. That energy is supplied from the cheapest sources for which infrastructure is already in place - fossil fuels.

99. In order to break these trends, capital should be invested in energy-sector development in rural and remote areas and directed towards renewable energy sources. In many cases, renewables can provide energy services at least cost. Providing energy services to remote and rural areas will have three immediate impacts: (a) improved living conditions, (b) improved food and agricultural production and (c) diminished rural migration. Such results, if achieved in an environmentally benign way, are conducive to sustainable social development.

100. Utilizing renewable energy sources can provide training, employment and development opportunities that otherwise would not be available. The scale of facilities for manufacturing and assembling renewable energy technologies (wind turbines, photovoltaic cells, biomass systems and solar thermal systems, in particular) can be comparatively modest. Developing nations can establish endogenous manufacturing capabilities for such technologies. In these ways, a renewable energy system can contribute to local economic development and may be able to reduce foreign debt by reducing both energy and technology import expenditures.

D. Security

101. Access to secure energy supplies at acceptable prices is a key objective of all nations. In general, this can be achieved if energy resources and the infrastructure for utilizing them are within a country's own borders or if a country has access to a functioning and reliable world energy market. Neither of these conditions currently exists for most countries.

102. Security-related aspects of energy issues can no longer correspond only to threat criteria generated by analyses of geopolitics, access to energy resources, transport, and price stability. Energy security must be based also upon safety, sustainability and environmental criteria.

103. In 1990, 40 per cent of world commercial primary energy consumption was of oil. This strong and broad dependence on oil has created strategic economic interests that lead to political crises, military conflict and economic vulnerability. The Gulf crisis, a case in point, clearly demonstrated the health and safety risks to mankind, as well as the environmental risks and economic vulnerability, caused by overdependence on resources that are not widely distributed across the globe. Globally, there was an increase of about $53 billion in the oil import outlay in 1990 compared with 1989: $41 billion from industrialized countries, $2 billion from the countries of Eastern Europe and $10 billion from the oil-importing developing countries. 20/ A significant share of the increase can be attributed to the Gulf crisis. The expenditures were particularly detrimental to the least developed countries and several countries in Eastern Europe, and their exposure to such risks should be a key factor in national and international evaluations of the viability of existing and proposed energy systems.

104. The use of nuclear power technologies must be curtailed because of the linkages between nuclear power and nuclear weapons, and the implications of nuclear weapons proliferation for the hazards of international conflict. Uranium-based nuclear power generation results in the production of plutonium, a highly toxic weapons material. About 200 kilograms (kg) of plutonium are produced per gigawatt year of power generated in a light-water reactor. A quantity on the order of ten kilograms is needed to produce a simple nuclear bomb. 21/ In order to reduce the risks of nuclear weapons proliferation, it is necessary to severely limit access to nuclear power technology. 22/

E. Finding solutions

105. The World Energy Conference (WEC), reflecting the thinking of the world energy industries, published a study at its latest congress illustrating the present energy path. 23/ The Conference scenario projects a 75 per cent increase in energy demand by the year 2020, despite assumptions of lower energy intensities in the overall economy, and in the Conference projection a conventional supply mix will be used to meet that demand. In contrast to the current trend of rapidly decreasing investments in new nuclear power plants, 24/ global nuclear capacity will increase by 340 per cent (an increase from 4 to 8 per cent of the total primary energy supply). In addition, renewable energy use will increase from 6 to 10 per cent of the total primary energy supply. The remainder of the demand will be met with fossil fuels. Scenario projections result in a 69 per cent increase in 1985 levels of CO_2 emissions by 2020. Such a future for energy would be unsustainable.

106. While much of the rationale behind the Nairobi Programme of Action is still valid, many of the reasons for utilizing renewable energy sources have been strengthened because of environmental concerns (especially that over the threat of climate change) and pressing development needs.

107. Technically available and cost-effective efficiency measures are sufficient to reduce energy-related carbon dioxide emissions by at least 20 per cent by 2005 in many industrialized countries. 25/ Efficiency measures can also play a large role in developing countries, where the level of services provided by future energy supplies can be significantly increased. 26/ Nuclear power may provide an increment of electricity in specific cases, although the high costs of nuclear power facilities, their long lead-times, and the risks associated with accidents, terrorism, waste disposal and nuclear weapons proliferation all present formidable barriers to increasing global nuclear capacity. Such concerns about nuclear power have led to considerably decreased investments in nuclear energy since the mid-1980s. Providing required quantities of energy services while simultaneously protecting the environment requires, therefore, a combination of efforts to improve energy end-use and conversion efficiencies and increased use of renewable energy sources.

108. We recognize that changing to a sustainable energy path based on energy efficiency and the utilization of renewable energy sources is a substantial task. The fundamental changes required will only come about through our learning to think in new ways. Environmental, developmental and security issues are forcing a paradigm shift towards conserving resources, minimizing pollution, preventing degradation of the natural environment and promoting economic growth and social development. That paradigm shift has been duly endorsed and supported by Governments, national and international institutions and enterprises, and the international community.

IV. RESOURCES, TECHNOLOGIES AND POTENTIALS 27/

A. Renewable-energy technologies: an overview

1. Resources: applications and impacts

109. The flow of renewable energy to the Earth's land surface is thousands of times greater than mankind's present rate of total energy use. The challenge consists in finding environmentally benign and economical techniques for using that renewable energy. 28/

110. Renewable-energy technologies can be used for a variety of applications that are able to meet practically every type of final energy demand. The product or technology considered can yield electricity directly, or heat, or mechanical power, or chemicals to be used as fuels. Because of this flexibility in producing modern energy carriers, the use of renewable energy sources is well suited to the energy systems of both industrialized and developing countries. The present degree of maturity of a variety of renewable energy technologies is indicated in table 4.

111. The utilization of renewable energy sources will lead to environmental impacts. The character and level of those impacts will depend on the technologies used and, most importantly, on the procedures and practices employed. Generally, the environmental and health problems associated with using renewable energy technologies, if prudence is respected in their employment, are much smaller than those of conventional energy sources. In particular, the use of renewable energy technologies does not result in greenhouse gas emissions.

2. Hydropower

112. Large-scale hydropower plants have been built in all regions of the world. Hydropower provides about 18 per cent of the world's electrical energy, and is the largest renewable energy source in most industrialized countries. Pumped-hydropower plants play a role in storing energy for peak-load demands.

113. In developing countries, a substantial share of aid funds made available for energy investments - in particular by the World Bank - has gone to large-scale hydropower projects.

114. Hydropower plants are primarily based on mature technologies. New developments are going on, however. Significant examples include the introduction of roller-compacted concrete that reduces the cost of concrete dam construction and recent progress in underground work technology.

Table 4. Degree of maturity of various renewable energy technologies and applications

Technology	Degree of maturity a/				
	1	2	3	4	5
Solar energy					
Solar absorbers	X				
Solar collectors (low temperature)	X		X		
Solar collectors (process heat)	X	X	X		
Solar thermal electricity (troughs)	X	X			
Solar thermal electricity (other technologies)				X	
Passive solar in buildings	X	X	X		
Photovoltaic (PV) electricity (crystal silicon [x-si])	X	X	X		
PV electricity (amorphous silicon [a-si])				X	X
PV electricity (other materials)				X	X
Solar production of energy vectors (for example, hydrogen), photochemistry					X
Wind energy					
Installations up to 400 kilowatts (kW)	X	X	X		
Larger installations				X	
Hydro energy					
Large-scale hydro	X				
Small-scale hydro	X				
Tidal energy		X			
Wave energy				X	
Biomass energy					
Combustion	X	X		X	
Gasification	X	X		X	
Bio-alcohol	X	X			
Vegetable oil		X		X	X
Other energy crops				X	X
Geothermal energy					
Geoscientific foundation				X	
High-T reservoirs	X				
Low-T reservoirs	X	X		X	X
Hot dry rocks				X	X
Ambient heat					
Electric heat pumps	X				
Absorption heat pumps	X	X	X		
Applications and components					
Photovoltaic (PV) application technologies (for example, pumps and lights)	X	X		X	
Batteries, fuel cells	X	X	X	X	X
Control system	X			X	
Heat storage	X		X	X	
Hydrogen (electrolysis, storage, handling)	X		X		

Source: "Förderung und nutzung 'erneuerbarer energiequellen' in der Bundesrepublik Deutschland", Deutscher Bundestag, drucksache 11/2684 (July 1988).

a/ Denoting: 1. Technically mature for market and possibly with need of optimization; 2. Application experience still missing (for example, lifetime of equipment); 3. Research and development needed for alternative solutions; 4. Development needed; 5. Research needed.

115. The cost of building and operating hydroelectric power plants depends very much on the site, financial conditions (for example, cost of capital), construction times and the extent to which the costs of externalities are incorporated in total costs. Hydropower plants are relatively simple and inexpensive to operate. Capital costs account for nearly all of the market-internalized cost of producing hydropower. The availability, therefore, of capital at low interest rates, and short construction times, can reduce hydropower generation costs. Typical investment-cost estimates for new projects range between $1,500 and $3,000 (1986) per kilowatt ($[1986]/kW) of installed capacity, excluding transmission costs and interest during construction. (Where constant United States dollars are used, the relevant year is given in parenthesis.) No simple scale factors are applicable, at least above 100 megawatts (MW) of power. Deducing the cost per kilowatt hour (kWh) from these data is not straightforward, since it depends on the capacity factor, credits for multiple uses of the plant, the distance from end-users and the extent to which externalities are incorporated. In some cases, kWh costs can be very favourable. Hydro plants may have lifetimes of a century or more (with replacement of some equipment), and after the initial investment is repaid, the cost of the electricity they produce is very low.

116. In industrialized countries, the remaining number of suitable large-scale environmentally acceptable hydropower sites are limited. A large potential remains in developing countries and in the Union of Soviet Socialist Republics. In these countries, however, applications are limited by the scarcity of capital, adverse environmental effects and, often, by the cost of large-scale distribution grids. Although recent advances in electricity transmission, especially in high-voltage direct-current (HVDC) lines, have increased the economically viable distance between electric power plants and end-users to on the order of 1,000 kilometres, technical, financial and environmental problems associated with the construction of HVDC lines have constrained the construction of large-scale plants. In addition, some favourable sites are still too far away from potential customers (particularly industries).

117. Even when suitable hydropower sites are located in satisfactory proximity to electricity demand, they may compete with other water and land uses. In order to improve prospects for new hydropower plants, it is necessary to devote increased attention to integrating the plant with other water uses. Water management and irrigation schemes can often benefit from the incorporation of a hydropower component. Where the main purpose of the scheme is hydropower production, designing with flexibility for incorporating other uses can often be beneficial.

118. Water impoundment may require local population displacements. Even when this is not the case, social disturbances in local communities are commonly produced.

119. A traditional procedure for building hydropower plants in developing countries has been to use components manufactured in industrialized countries and to rely on local enterprises for the labour. This procedure has a number

of limitations. First, as mentioned previously, many components are presently built in developing countries. Second, not all developing countries have adequate know-how for the special construction needed in hydraulic plants. Organizational and training problems associated with large-scale plants have created difficulties in developing countries. Technology transfer and training should be provided. Geological complications in developing countries have sometimes created problems and led to cost overruns.

120. The potential negative environmental impacts of large dams include erosion, sedimentation, damage to flora and fauna, climatic effects, seismic effects and spread of diseases, such as schistosomiasis. Dam safety is also a major concern.

121. Small-scale and mini hydro plants (up to a few MW) pose fewer problems than large-scale projects, and their diffusion in the last 10 years has been significant but less than predicted. Hydraulic and electric equipment producers have made a considerable effort to improve the quality and lower the costs of components. Improvements have occurred in such areas as design standardization, manufacturing, choice of materials, automation and remote operation. Production in this industry has been concentrated within a limited number of companies, with positive effects on costs and standardization. Some of the companies of international importance are located in developing countries, such as China, and in South America.

122. Innovations ranging from new dynamic seals to inflatable rubber transverses, from simple control systems to devices that facilitate fish transit, have improved many aspects of mini hydro plants. In some cases, traditional concepts have been revived with new materials and improved design. Many schemes for integrating water uses have been implemented.

123. Less progress has been made in the development of microhydro plants (stand-alone plants, that is, plants that are not grid-connected, and generally below 100 kW), especially where components are concerned. Components designed for other uses, such as pumps and other types of generators, are often employed. Electronic load controllers that replace expensive and unreliable mechanical governors have been one positive development. A number of successful microhydro plants have been installed in several countries. The United Nations-sponsored Hangzhou Regional Centre (Asia-Pacific) for Small Hydropower, in China, has played a positive role in many such installations. Progress has been made in some countries (notably China and Nepal) in the local manufacture of plants. Such experience could be transferred to other developing countries.

3. Fuelwood and charcoal

124. Fuelwood continues to play a major role in many developing countries, where it represents the largest contribution to the energy supplied to rural populations. Conventional fuelwood supplies and use often result in, or contribute to, major environmental problems such as deforestation and land

degradation. The health impacts of indoor biomass combustion afflict at least 500 million women and children. 29/ The sustainable provision of fuelwood and its environmentally sound use need to be high priorities. The low energy efficiency with which wood is used has prompted the establishment of a number of programmes to develop and diffuse wood stoves for cooking and heating that are much more energy efficient than traditional stoves. Some of these programmes have been successful, especially those that addressed local social and cultural barriers. In China, 120 million fuel-saving stoves are reportedly in use. 30/ In other countries, energy-efficient charcoal stoves are used in urban areas, where, unlike in rural areas, both fuel and stoves are costly commercial commodities.

125. Charcoal is also produced for industrial uses. The most important example of industrial use occurs in Brazil, where over 7 million tons of charcoal is used annually in place of coal for pig-iron and steel production and yields iron with better magnetic qualities than that achieved with conventional furnaces. 31/ Charcoal is generally produced with primitive earthen kilns that have an overall energy conversion efficiency of less than 25 per cent. 32/ Important improvements have begun to be introduced in several countries. Improved earthen kilns can achieve energy efficiencies of about 50 per cent. Sophisticated and well-managed kilns can achieve energy efficiencies of 60-70 per cent. 33/

126. Notwithstanding some improvements in fuelwood transformation and utilization, the situation on the whole is not much better today than it was 10 years ago. The trend toward deforestation and desertification has continued, especially in semi-arid and mountainous regions, often for non-energy reasons. Further improvement in fuelwood use should be based on an assessment of past programmes and on learning from past failures. New programmes should be designed in a broader context, including programmes for sustainable forest management, consideration of fuel collection and storage problems, use habits, the role of women, health issues, and barriers to commercialization and market penetration. Many difficulties must be overcome in order to implement such integrated programmes including problems of land tenure, trees and wood related to reforestation programmes; wood use for other productive activities; and the need to formulate effective policies for managing resource substitution and energy transition.

127. In cases where fuelwood is increasingly scarce and cannot be used renewably, it is necessary to shift to different energy sources, such as fossil fuels like kerosene or liquefied petroleum gas (LPG), or to sustainably managed bioenergy sources, such as agricultural residues and energy crops. Wood use should be promoted only when managed in a sustainable manner.

4. Biomass: energy crops and wastes

128. Sustainable biomass utilization as an energy source can be viewed from two complementary points of view - that of the biomass resource and that of the technology used for its transformation and utilization. Biomass for energy use can be either derived from residues or by-products of food - and other production processes, or cultivated.

129. The accumulated experience with biomass technologies is much greater today than it was at the time of the United Nations Conference on New and Renewable Sources of Energy. A wide range of technologies exist for transforming and utilizing biomass. Some are well established, such as direct combustion. The United States of America alone has nearly 9,000 megawatts (MW) of biomass-produced electricity-generating capacity, mostly from agricultural and silvicultural residues. With an average capital cost of $1,500 (1989)/kW and a fuelwood cost of 1.2-2.4 cents/kWh, the resulting total generation cost in the United States is between 4.2 and 5.4 cents/kWh. 34/ Other technologies are still in the research stage, such as enzymatic hydrolysis of cellulosic materials to produce ethanol, and biomass gasifiers coupled to combustion turbines to produce electricity. All of these technologies have been improved in the last decade. Most of the advanced conversion technologies with the greatest promise, however, still remain in the development stage.

130. Energy crops may compete with food crops for land utilization. In circumstances where agricultural land is not too limited, energy crops may be an option. The use of marginal lands for energy crops should also be considered. The very large-scale production of ethanol fuel from sugar cane in Brazil (11 million tons in 1990 under the ProAlcool Programme) has shown that such a process is indeed possible and economically competitive in the context of higher oil prices and improved technologies. 35/ The sugar- and ethanol-producing industries generate large quantities of bagasse, which up to now have been only partially utilized. Bagasse use in an efficient co-generation plant could produce the heat requirements of the sugar industry and up to 40 times more electricity than the industry needs. Electricity sales to the grid could generate revenue comparable with that from sugar and alcohol sales. This innovation alone could make bio-ethanol competitive with oil, even at present low oil prices. 36/ The stillage from the same industries, when simply dumped into rivers, can be a major source of water pollution. It can, however, also generate significant quantities of biogas, producing residues that are more suitable for fertilization than the original liquid. Similar situations exist, for instance, in the fruit-processing and vegetal-oil-producing industries.

131. Energy crops are also of interest in countries where agricultural productivity increases resulting in food surpluses make fertile land available for other uses. Such land can be used to grow energy crops, several species of which are already available. Genetic improvements (including advanced biotechnologies) in wood and herbaceous crops and development of appropriate processing methods for additional species are required. Aquatic biomass

production may also provide a future source of energy crops. The use of oleaginous plants to produce oils for use in diesel engines is another possibility that is receiving increased attention.

132. Many of the potential environmental problems associated with using energy crops, such as reduction of biological diversity, pollution from pesticides and fertilizers and competition with alternative land uses, are common to other agricultural activities. On the other hand, the environmental advantages are important. They include avoiding the negative environmental impacts of the substituted energy sources (in particular CO_2 emissions from fossil fuels), alleviating the depletion of forests and woodlands and avoiding land degradation in cases where agricultural land would otherwise be abandoned.

133. While at least a part of agricultural residues should be recycled on site to fertilize the soil, many agricultural, urban and industrial organic residues and wastes are still available. Utilizing them for energy often solves environmental problems. Food industries, which are often the first industries in developing countries, produce organic wastes that can be transformed into methane (via anaerobic digestion) or used for heat and/or electricity generation, which in turn can be used, at least in part, by those same industries.

134. Large cities generate tremendous amounts of solid and liquid wastes, which constitute formidable environmental problems. However, these wastes, if properly collected and treated, could yield valuable energy for urban use. Gas production from municipal solid waste (MSW) landfills and the burning of MSW directly or through residue-derived fuel production for electricity generation are useful options. Much of the combustible waste, however, is often collected and used by the poor before it reaches the incinerator. Anaerobic fermentation of liquid wastes or sludge, with biogas production, can eliminate or at least reduce the need for external energy supply for waste water treatment. In general, processes that avoid uncontrolled fermentation of wastes and releases of methane to the atmosphere are doubly important in terms of global climate - for their energy value (and therefore for achieving an avoidance of the effect of the fuel they replace) and their removal of a methane emission source. The use of wastes and residues is generally positive from an environmental point of view because it removes potential pollution problems.

135. Very simple technologies based on local materials and capabilities have not always lived up to expectations. One example is anaerobic digesters: the simple backyard type, widely diffused in some countries (notably China, where several million household plants are still in operation) 37/ has had operation and endurance problems. In many cases these have been replaced by systems that are still simple but incorporate somewhat more sophisticated technologies. The blending of improved and even advanced technologies with traditional concepts has, in many cases, proven to be a successful approach.

136. There are many emerging biomass technologies with large potentials. We

mention only a few. Gasification of crop residues, such as rice husks, is receiving some attention in South-East Asian and Latin American countries as more effective than direct combustion. Pilot plants of this type are operating in China and Indonesia. A concept that has raised some interest, but is not yet diffused in field use, is the coupling of gasifiers with gas turbines for electricity generation. Another example of a promising technology is the treatment of cellulosic materials by steam explosion, which may be followed by biological or chemical hydrolysis to produce ethanol or other fuels. Cost projections based on presently available technologies are on the order of 25 cents per litre (cents/l), but expected improvements could lower those cost projections to 15 cents/l. 38/ Small Stirling (hot air) engines, capable of using wood or agricultural residues as fuel, have recently received renewed interest. Pyrolysis of various biomass products to generate liquid bio-fuel or a bio-oil/bio-coal slurry that could replace fuel oil in existing power plants is being investigated, particularly in the European Community.

5. Solar thermal

137. A large number of different technologies and applications are available for direct thermal and indirect (through thermodynamic cycles) uses of solar radiation. Some of them have been significantly improved in the last decade, some are still of uncertain success and others are being abandoned.

138. Passive solar heating and cooling of buildings, a practice that has traditional roots in many countries, has been revived in recent years by applying modern analysis and computing methods. Efforts have recently been made to blend new methods with local materials and building practices. Such schemes can have important effects on both comfort and building energy consumption in both rural and urban areas. When passive solar features have been introduced in the initial design stage and appropriate solutions used, the extra costs involved have proved to be modest - typically 5-10 per cent of the total cost of the building. Those extra costs are partially recuperated by allowing for downsizing of heating and cooling equipment. The net costs are paid back with energy bill savings in very few years. In addition, comfort levels are usually better than with active/conventional systems. Retrofitting passive solar features into existing buildings is also possible in some cases, but the economics are very case-specific.

139. Solar water heaters have been steadily improved: methods of producing collectors have gotten cheaper, control systems are better and simpler and components are more rugged and reliable. However, their diffusion has been slower than anticipated. They provide hot water, which is not widely available in many developing countries, at prices which are competitive with electricity, especially with respect to prevailing inefficient heaters. In industrialized countries, they are not yet competitive with natural gas where it is available. In several countries solar water heaters cannot compete with liquefied petroleum gas (LPG) because of high LPG subsidies. Efforts are needed in most countries to provide cheaper and better installation and

maintenance services. Nevertheless, 1.8 million square metres of solar collectors for water heating are in use in China. 39/

140. Solar driers for crops are a promising technology that still needs development. They can be built using simple schemes and inexpensive materials, but should include a minimum of temperature control in order to achieve optimum results on various types of crops. They can effectively replace oil-burning driers and help to avoid post-harvest losses common to traditional open-air natural drying practices. Year-round applications, such as timber drying, or integrating different applications provide favourable investment returns. When waste products are available for fuel use this can represent a practical approach.

141. Solar cooker applications that replace inefficient wood stoves have met with difficulties, especially when their introduction has not taken local traditions, such as cooking early in the morning or at night, or cooking indoors, adequately into account. Lack of availability in cloudy weather is another difficulty.

142. High-temperature solar heaters (reaching well above 100° C) can be built by concentrating solar radiation and/or using special materials. Fluids at such temperatures can be used in a number of applications, including refrigeration (by means of absorption coolers); desalination, for example, by a multi-flash process; and processing heat or steam for industrial uses. Applications of all these types have been reported and in many cases they have been a technical success. However, for the time being their diffusion is very limited, primarily for economic reasons.

143. Solar ponds both collect solar energy and store it as heat for relatively long periods. They can be economically interesting under rather special circumstances, in particular when salt is freely available and natural enclosures can be used for the pond. A number of solar ponds exist or are being built in several countries. The largest pond in operation is in Israel, on the edge of the Dead Sea; it generates 5 MW of electric power. 40/ Others are being used for desalination and for heat storage.

144. Solar thermal electricity can be obtained with several different technologies through thermodynamic cycles operating at relatively high temperatures. Those temperatures can be obtained through different types of concentrators: mirrors aiming solar radiation at a central tower, parabolic dish collectors and parabolic troughs. Only parabolic troughs have met with success so far. Through an Israeli-American venture, a number of power-generating solar installations have been built. Those installations now total over 350 MW and are being expanded to 700 MW in southern California. The cost of trough concentrators has decreased to about $\$200/m^2$ and electricity is sold to the grid at competitive prices.

145. Solar thermal systems lead to very few environmental problems, other than those deriving from their surface area requirements - a direct consequence of the distributed nature of solar radiation. This problem is minimized when

solar collectors are integrated into existing structures or occupy areas not otherwise usable. Some solar thermal systems (for power production and for refrigeration) use chlorofluorocarbon (CFC) fluids. Alternative fluids exist and will be used in the future.

6. Solar photovoltaic

146. Photovoltaic (PV) technologies directly convert solar insolation into electricity. Although in general much more expensive than other electricity-generating technologies, they are considered very promising. 41/ There are three reasons for this: (a) they are highly innovative and based on components that are under rapid development and therefore have a large potential for cost reduction as production volumes increase, (b) they are almost scale-independent (and this feature makes even very small plants relatively interesting) and (c) they require very little (if any) intervention for operation and maintenance.

147. PV system costs have declined by at least one order of magnitude since 1970 to about $7,000/kW, of which about $4,500 is reserved for the PV modules and $2,500 for the rest of the system. With an electricity-generating level of 2,200 kWh/kW per year, a plant life of 30 years and a 6 per cent real discount rate, PV electricity currently costs about 30 cents/kWh. 42/

148. Even though their costs are currently much higher than those of conventional energy sources for bulk electricity production, PV technologies are already competitive in many market applications, such as telecommunication, cathodic protection of pipelines, signals at sea and consumer electronics. In developing countries, applications also include the provision of drinking water, health care and lighting. The size of these intermediate markets has increased rapidly as the prices of PV systems have decreased. PV sales have grown steadily, doubling every four to five years, to the present level of about 50 MW/year. 43/

149. As PV prices decrease, PV technologies become increasingly cost competitive with diesel generators for power supply to locations not connected to grids. Such locations, however, are mostly found in rural areas of developing countries, where people often can hardly afford a diesel generator and little capital is available for the high initial investment costs associated with PV systems. PV applications should be combined with high-efficiency end-use appliances, thereby optimizing the entire supply/utilization system in terms of cost of delivered energy services. Hybrid systems, combining PV and diesel generators, with PV providing between 35 and 70 per cent of the energy, can greatly reduce the need for electric storage. Other hybrid systems, like PV and wind or PV and biomass, are also being explored.

150. Promising applications have recently been identified in special large-grid situations. PV system grid reinforcements may be cost-effective in the near future in parts of the distribution network that are far from generating

stations, have large quantities of insolation and a good match between insolation and load, and experience high costs for alternative generating solutions. If utilities adopt a more detailed, space-dependent system of cost analysis that takes into account demand-side management, the short- and medium-term potentials of PV are likely to be positively re-evaluated. In the longer term, increases in conventional fuel prices, more stringent environmental regulations and availability of capital at low interest rates are factors that would facilitate the penetration of PV systems. Continued diffusion of grid-connected applications of PV systems in industrialized countries in parallel with the diffusion of stand-alone applications in developing countries would increase the PV market, thereby driving down production costs.

151. PV system prices are expected to decline further in the future, as a result of both economies of scale in manufacturing processes and a shift to cheaper new materials. The largest industrial plants now produce a few megawatts per year: a factor of 10 scale-up would reduce cell production costs by a factor of about 2. In order to reduce material costs for crystal silicon (X-Si) technologies, it will eventually be necessary to rely on thin films. One such candidate is amorphous silicon (a-Si). 44/ Although its production costs are already much lower than those of crystal silicon, amorphous silicon's present characteristics of low efficiency and initial degradation have slowed its penetration into the general energy market. So far, its applications have been limited to consumer electronics and gadgets, but wider applications may be approaching.

152. PV cells composed of multiple layers of amorphous silicon have produced higher efficiencies and improved stability. Still higher efficiencies (above 13 per cent in the laboratory) can be obtained by using layers of different materials, such as a-Si and amorphous germanium (a-Ge), or different silicon-germanium alloys (Si-Ge), in which each material optimizes the utilization of the various wavelengths of solar radiation.

153. Other materials are being investigated as candidates for PV cells. Among them, gallium arsenide (GaAs), which is also of interest for electronic applications, can be manufactured in thin films. Copper indium diselenide (so-called CIS) and cadmium telluride (CdTe) are other materials that appear promising and are receiving attention today.

154. As a result, first, of crystal silicon production improvements and economies of scale and, later, of the introduction of thin-film technologies and various reductions in other system costs, the total cost of PV systems is expected to decrease to $2,500-$3,500/kW by the year 2000 (with electricity costs between 10 and 15 cents/kWh) and perhaps to $1,000-$1,500/kW by the year 2020 (5 to 6 cents/kWh). 45/

155. As with solar thermal technologies, PV systems have large space requirements. Similar opportunities for reducing them are available. The promising approach of PV concentrators for electricity production offers the potential of high conversion efficiency at low cost because concentrators

permit the use of small areas of high-efficiency cells coupled with low-cost lenses or mirrors. 46/ PV module production presents potential environmental impacts similar to those of the electronics industry - use of CFCs as cleaning agents and possible toxicity of components for non-conventional materials such as GaAs and CIS, among others. Such problems can be and are being overcome.

7. Geothermal energy

156. In the last decade, global geothermal electricity-generation capacity has increased from 2,000 to 5,830 MW and from 500 to 2,000 MW in developing countries. Technological developments for tapping geothermal sources have taken place, particularly in the Philippines, Mexico, Nicaragua and El Salvador. The use of lower-enthalpy geothermal fluids for heating purposes in urban buildings, greenhouses, aquaculture and animal breeding, for example, has expanded (mostly in industrialized countries because of the lower demand for space heating in developing countries).

157. Technologies for harnessing geothermal energy are mature but technical improvements are constantly being made. 47/ Within the last decade such improvements have included the ability to modulate the load in an economic and efficient way in both steam- and water-dominated situations, even for relatively small plants; the building of simple and reliable single- and double-flash systems at moderate cost installed in remote locations; the development of new techniques for drilling deep wells (4,000 metres and beyond) through hard, hot rocks; the improvement of materials and sealing techniques; techniques for drilling multiple wells branching off main wells at great depths; the drilling of quasi-horizontal wells; and the improvement of geophysical and geochemical prospecting and evaluation methods.

158. The costs of direct heat applications are difficult to evaluate but, in general, cost-competitive direct geothermal heat applications are limited. Under favourable conditions, however, the cost of electricity generated with geothermal heat is competitive with the cost of electricity generated from conventional sources. A general evaluation, which takes into account all phases of electricity production starting from surface exploration and feasibility studies, yields a cost range of 3-8 cents/kWh using a 6 per cent real discount rate. The costs of direct heat applications vary much more because they depend not only on the characteristics of reservoirs but also on the presence of potential users close to the drilling site.

159. New techniques for utilizing geothermal reservoirs are being developed and diffused. They include, for example, using geothermal heat for chemical processing and producing pure water from the plant. Promising improvements have been made in the development of hot dry rock (HDR) technologies. The availability of HDR technology would extend the geothermal resource base to many more countries.

160. Measures for reducing the negative environmental impacts of geothermal plants are implemented much more widely today than they have been in the

past. Re-injection of water and dissolve wastes is now a universal practice. Gaseous-pollutant emissions, such as hydrogen sulfide (H_2S), are also being avoided with increasing efficiency. The costs of such measures are already being included in economic evaluations of geothermal projects.

8. Wind energy

161. In areas with adequate wind patterns, wind turbines are presently the cheapest renewable energy source for producing electrical and mechanical power, with the exception of some hydropower. 48/ Wind patterns are very variable. Ground configurations around the wind turbine and the presence of vegetation have important effects. It is necessary, therefore, to have accurate measurements and evaluations of actual conditions on each site considered for wind turbine installations. 49/

162. Wind power technologies have evolved remarkably in the last decade. However, most of their evolution, and most of the new applications of wind turbines, have been concentrated in industrialized countries and designed to suit their conditions. Wind turbines provide electricity to the grid in California (over 1,500 MW), Denmark (350 MW), India (40 MW) and the Netherlands (40 MW). Electricity production costs decreased by an order of magnitude in the 1980s and currently are roughly equal to the costs of electricity generated by coal-fired plants. The average power of the turbines employed has risen steadily in the last 10 years, from a few tens to a few hundreds of kilowatts. Large-scale turbines (generating one or several MW of power) are still at an experimental stage, and it is not clear, outside of cases where space is limited and in offshore applications, whether they will eventually become more cost-effective than medium-sized ones.

163. Recent wind technology developments include advanced airfoils and variable-speed turbines that employ solid-state advanced electronic power-conditioning systems. There has also been continued development of new materials that yield lighter, stronger components. Energy capture has increased 10 per cent or more, while capacity factors that were in the range of 15 per cent 10 years ago are now as high as 35 per cent. All these improvements are directly reflected in lower electricity-generating costs.

164. In developing countries - where environmental conditions may be more severe (and sand-carrying winds common), average wind velocities lower and reliability particularly important - stand-alone systems may be required rather than grid connected systems. However, it is important to draw from the experience already gained by industrialized countries, where turbines have been tested for several years and have penetrated the market with great success.

165. Smaller-power turbines (up to a few kilowatts) have long been used in many countries for pumping water for use by humans and cattle, for irrigation and for charging batteries. In industrialized countries, such practices declined with the expansion of rural electrification. However, the demand for

those applications is large in developing countries. Wind pumps are economically attractive, at least for drinking water, even when average wind velocities are low. About 110,000 wind generators and 1,600 wind pumps are operating in China. 50/

166. Modern wind technologies are more reliable, lighter and cheaper than traditional ones. Positive results have also been obtained by using locally available materials and by varying traditional schemes in modern applications.

167. Environmental problems associated with wind generators have been extensively investigated in connection with major installations. 51/ The effects considered included damage to birds, electromagnetic disturbances to television transmissions, noise, and aesthetic alterations of landscapes. Apart from the last, which is a matter of personal evaluation, environmental impacts have proved to be minor or negligible.

9. Other energy sources

168. Several different energy sources are present in oceans: tides, currents, waves and thermal gradients. 52/ All of these energy forms are only available at nearshore locations and are therefore particularly interesting on islands. Their potentials also vary considerably with location. Only the case of tides has been demonstrated: a 240 MW plant exists in France and smaller ones exist in the Soviet Union and China. Several other tidal projects are being considered. Only a minute fraction of the 3 terawatt (TW) tidal resource, however, can even be theoretically captured. The other ocean technologies are at the experimental or conceptual design stages, and there are no prospects for large-scale utilization, at least in the next 10 to 30 years.

169. The use of animal power in agriculture is important and can be improved with appropriate technologies, such as more efficient harnessing devices, more appropriate tools and implements (pumps, for example), better breeding, health care and feeding programmes. Using animal power can also be advantageous in swamps and in areas where soil could be damaged by machinery.

B. The annual economic supply potential

1. Factors affecting the annual economic potential

170. An assessment of the economic potential for supplying energy with renewable resources begins with an appraisal of existing technologies and unsubsidized production costs, even if (given the numerous factors influencing the estimates) such an appraisal is difficult to make. The economic potential changes over time as a function of technological and other cost-reducing progress, changes in the cost of renewable energy technologies and changes in the prices of competing energy sources. In addition, subsidies for conventional energy sources, in place in many countries, may largely reduce the accessibility of the economic potential.

171. The proximity of populations to renewable energy sources and the range of energy carrier transmission capabilities are also important factors.

172. Various non-economic constraints affect the economic potential for renewable energy production and use. These include the variable nature of many renewable energy sources over time (diurnally as well as seasonally); the diffuse nature of some renewable sources; and the availability of sufficient infrastructure and skills to construct, operate and maintain renewable energy systems.

2. The annual economic supply potential: 1991-2000

173. The annual economic potential for supplying energy with renewable resources by the year 2000 has been estimated in a study prepared for UNSEGED by Dessus and others. 53/ Their estimates were based on commercially available proven technologies and existing equipment production costs, current market prices for fossil fuels and a 5 per cent real discount rate for all technologies considered and compared. They found that, globally, 1985 levels of renewable energy production (see table 5) could more than double, from a limited economic point of view, during the 1990s.

174. The economic potential for renewable energy supply by the year 2000 is disaggregated into four northern and six southern regions in table 6. The economic potential for electricity production based on primary renewable energy sources by the year 2000 equals approximately half of the 1985 total global electricity production (see table 7). Countries in the southern hemisphere generally have larger potentials in relation to their current production than do countries in the northern hemisphere.

175. Technological development is not required to increase the use of renewable energy sources to the levels indicated in tables 6 and 7. Barriers to utilizing the available potential include limited equipment manufacturing capacity, capital constraints, direct market barriers, inadequate institutional structures, and the organization of the energy industry. New technologies face the additional challenge of requiring very high market penetration rates in order to take over significant shares of the energy market. For example, although PV sales have doubled every four to five years, the total amount of installed PV capacity is very low. It would take 30 to 40 years at the current growth rate (about 20 per cent per year) before PV technologies could provide a significant share of world energy supply. Great efforts should be made on the part of Governments, industries and utilities to accelerate such growth rates.

Table 5. World Energy Conference estimates of the 1985 contribution of renewable sources of energy (RSE) to global energy supply

Hemisphere	Hydro	Geo-thermal	Solar	Wind	Biomass a/ WO c.	Biomass a/ WO n.c.	Biomass a/ BI crops	Biomass a/ Waste	Total RSE	Total energy	Total RSE share of total energy (Percentage)
	(Megatons of oil equivalent [Mtoe])										
Northern	312	8.5	8	0.8	98	22	2	10	461	5 352	8.5
Southern	133	3.5	5	0.2	77	583	8	80	890	2 317	38.3
Total	445	12	13	1	175	605	10	90	1 351	7 669	17.5
Total individual renewable sources of energy as share of total energy (percentage)											
	5.8	0.2	0.2	0.01	2.3	8	0.1	1.2	17.5		
Total individual renewable sources of energy as share of total renewable sources of energy (percentage)											
	33	1	1	0.07	13	45	0.7	7	100		

Source: B. Dessus, F. Pharabod and B. Devin, "Renewable energies: actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche, No. 1 (January 1992).

a/ Biomass energy is disaggregated into four categories. Commercial wood products derived from multi-use forests are designated as WO c. and non-commercial wood products so derived are referred to as WO n.c. Biomass cultivated strictly as energy crops is referred to as BI crops. Urban and rural wastes (including cattle and crop residues) are referred to as Waste. Primary electricity is counted in thermal equivalents using the heat rate adopted by the World Energy Conference (0.222 Mtoe per terawatt hours of electricity [TWh_e]).

Table 6. Annual accessible renewable energy supply potential by region and technology by the year 2000

(Megatons of oil equivalent [Mtoe])

Region	Hydro	Geo-thermal	Solar	Wind	Biomass				Total RSE
					WO c.	WO n.c.	BI crops	Waste	
North America	169	3.5	17.5	16.4	204	7.5	13.6	67	498
Western Europe	174	3	6.5	14	43	5	5.3	52	303
Japan, Australia and New Zealand	34	3.6	6.5	9.8	17	0	3.9	16	91
Soviet Union and Central Europe	180	3.1	7.5	1.8	218	15.5	15.4	56	497
Total northern regions	557	13.2	38	42	482	28	38	191	1 389
Latin America	144	1.5	17	1.8	324	158	15.7	55	717
North Africa and the Middle East	7.5	0.1	11	0.1	10	11	0.9	6	47
Africa	24.5	0.3	19.5	1.2	70	200	3.9	24	343
India	17.5	0	43	5.3	9	66	5.2	69	215
China	71.5	2.1	32	6.3	17	48	3.2	84	264
Asia and Oceania	56	2.7	39.5	3.3	68	162	2.8	65	399
Total southern regions	321	6.8	162	18	498	645	32	313	1 996
Total (world)	878	20	200	60	980	673	70	504	3 385
	Individual RSE as percentage of total RSE								
	26	0.6	6	1.8	29	20	2	15	100

Source: R. Dessus, F. Pharabod and R. Devin, "Renewable energies: actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche, No. 1 (January 1992).

Note: Passive solar heating and cooling of buildings, solar crop or lumber drying, solar ponds, offshore wind systems, mechanical energy (for water pumping, for example) provided by windmills, and tidal and ocean thermal energy conversion systems are not included in the table. Offshore wind plants are currently on the brink of commercialization in Denmark. Energy costs assumed by Dessus and his colleagues are as follows: solar water heating, 4-7 cents/kWh; PV decentralized, 50 cents to $2/kWh; grid solar electricity (PV or thermal), 30-70 cents/kWh; grid wind, 7-25 cents/kWh; decentralized wind 15-50 cents/kWh; hydropower, $1.2-$3/watt peak (Wp).

Table 7. Annual economic potential for primary electricity for the year 2000

(Terawatt hours [TWh])

Region	Hydro	Wind		Solar		Total	1985 production
		Grid	Remote	Grid	Remote		
North America	767	75	0.1	60	0.7	903	2 980
Europe	793	63.4	0.5	13	1.6	872	1 875
Japan, Australia and New Zealand	155	44.8	0.3	19	0.3	219	795
Soviet Union and Eastern Europe	816	8	0.7	24	0.8	850	1 710
Latin America	656	5	2.9	37	10.8	712	525
North Africa and the Middle East	34	0	1.2	21	9.5	66	200
Africa	111	1.5	3.6	15	25.8	155	185
India	80	5.2	18	13	63	179	260
China	325	9	18	13	33.6	398	450
Asia and Oceania	252	0	15.4	12	55	334	320
Total (world)	3 990	212	61	227	200	4 690	9 300

Source: B. Dessus, F. Pharabod and B. Devin, "Renewable energies: actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche, No. 1 (January 1992).

3. The potential for the year 2020

176. Beyond 2020, the economic potential for renewables may become enormous. The potential will increase for two reasons. First, progress along the learning curve for existing technologies and systems will lead to reduced delivered-energy costs. In addition, governmental support today for renewable energy technologies will help build up markets, thereby helping industry to achieve a place on the learning curve. Second, research, development and demonstration (RD&D) is likely to lead to cost reductions and new technologies and systems (for example, solar hydrogen). 54/ New opportunities will arise from the technological improvements and turnover of existing capital stock that take place between the years 2000 and 2020.

177. An example of the importance of RD&D is presented in The Potential for Renewable Energy: An Interlaboratory White Paper, prepared by five of the United States Department of Energy's national research laboratories. 55/ The study concludes that if federal RD&D expenditures were expanded two to three times (by about $3 billion during the next 20 years), renewable energy sources could provide 28 per cent of projected American energy demand (roughly half of current American energy consumption, or 1.9 Gtoe) by the year 2030.

178. Table 8 shows a highly conservative estimate of the economic potential for renewable energy supply in 2020. 56/ This estimate is based upon already proven technologies (without accounting for future technological breakthroughs) and today's energy prices. The increased potential shown in this table is a function of population growth and learning-curve effects, not of technological change. Technological development would increase the potential further. The economic potential corresponds, nevertheless, to more than half of present total global energy use.

4. Integrating supply and demand

179. In order to estimate the share of future energy supply that can be provided by renewable energy sources it is necessary to integrate estimates of the annual economic potential for adopting renewable energy technologies with scenarios of future energy demand. Demand scenarios vary considerably, depending on underlying assumptions. Assumptions regarding end-use efficiencies are often the most important sources of differences in demand-scenario results.

180. In the World Energy Conference scenario (WEC:M), global average energy demand grows at a rate of 1.7 per cent per year for the period 1985-2020, while annual economic growth is assumed to be 3 per cent. The energy-demand growth rate is slightly lower than the 1.9 per cent per year rate experienced between 1973 and 1985. In this scenario, global annual energy demand grows from 7.7 billion tons of oil equivalent (Gtoe) in 1985 to 13.5 Gtoe in 2020. 57/

181. The scenario presented by Goldemberg and others in Energy for a Sustainable World (ESW) indicates that energy demand can be restrained to 8.4 Gtoe in 2020 if energy efficiency is increased across all major end-uses and sectors to a level corresponding to that of the presently most energy-efficient technologies that are commercially available or close to commercialization. Such technologies are assumed to be introduced at the rate of capital turnover and expansion. 58/ A gross domestic product (GDP) indicator is not explicitly used in the ESW scenario. Social and economic growth assumptions in the scenario are consistent with a global per capita GDP growth rate of up to about 3 per cent per year. 59/ Developing countries are assumed to be successful in leap-frogging over the average energy end-use efficiencies presently prevailing in industrialized countries by acquiring highly efficient end-use technologies that are already commercially available or close to commercialization as development and capital expansion occur.

Table 8. Minimum annual accessible renewable energy supply potential by region and technology for the year 2020

(Megatons of oil equivalent [Mtoe])

Region	Hydro	Geo-thermal	Solar	Wind	Biomass				Total RSE
					WO c.	WO n.c.	BI crops	Waste	
North America	195	6.8	40	35	227	0	80	70	654
Western Europe	180	5.2	20	30	60	0	65	57	417
Japan, Australia and New Zealand	40	5.7	30	20	23	0	11	16	146
Soviet Union and Eastern Europe	240	5.6	30	15	250	0	34	62	636
Total northern regions	655	23	120	100	560	0	190	205	1 853
Latin America	245	4.1	60	12	500	120	70	86	1 097
North Africa and the Middle East	8	0.2	80	2	20	5	10	17	142
Africa	63	0.7	60	3	240	140	60	52	619
India	26	0	40	8	40	55	5	90	264
China	128	3.8	50	10	40	50	5	90	377
Asia and Oceania	90	7.2	60	10	150	130	10	80	537
Total southern regions	560	16	350	45	990	500	160	415	3 036
Total (world)	1 215	39	470	145	1 550	500	350	620	4 889
	Individual RSE as percentage of total RSE								
	25	0.8	9.6	3	32	10	7	13	100

Source: R. Dessus, F. Pharabod and B. Devin, "Renewable energies: actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche, No. 1 (January 1992).

182. By the year 2020, if the economic potential for utilizing renewable energy sources shown in table 8 is applied in the WEC:M scenario, approximately one third of global energy will be provided by renewables. The same renewable supply potential could supply half of global energy consumption under the ESW demand scenario.

C. Potential benefits with respect to global problems

1. Reducing demand for fossil fuels

183. By reducing the demand for fossil fuels, the utilization of renewable energy sources can achieve important benefits in the areas of environment, development, security and employment.

2. Avoiding greenhouse gas emissions

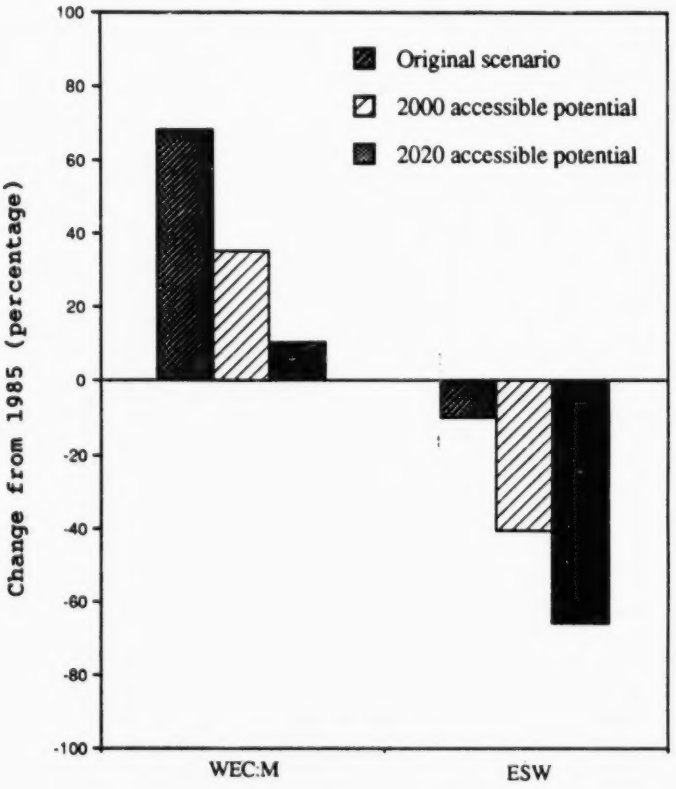
184. Meeting a larger share of energy demand with renewable energy sources would have beneficial effects on a key contemporary environmental problem: global climate change. Targets for reduction of greenhouse gas emissions could be met if renewable energy were employed extensively.

185. In the following analysis, published estimates of carbon-equivalents (C_{eq}), which allow for the inclusion of greenhouse gases other than the carbon that results from the combustion of fossil fuels, have been utilized. Fuel-cycle emissions associated with the mining, processing, transporting and burning of fossil fuels are included. The known effects of methane (CH_4) and tropospheric ozone (O_3) from methane oxidation are also included. 60/

186. The figure shows percentage changes in carbon-equivalent emissions between the years 1985 and 2020 resulting from two levels of energy demand (WEC:M and ESW) and three levels of renewable energy supply. Both the WEC:M and ESW scenarios assume that renewable energy supply increases between 1985 and 2020. Neither of the scenarios, however, assume increases as large as the 2000 and 2020 accessible potentials identified in tables 6 and 8. The original WEC:M scenario for 2020 would result in an emissions increase of 68 per cent compared with 1985 emissions. The original ESW scenario for 2020 would reduce emissions by 10 per cent. If the renewable energy supply potential presented in table 6 for the year 2000 were utilized, emissions would increase by 35 per cent in the WEC:M scenario and be reduced by 41 per cent in the ESW scenario.

187. The comparative costs of these scenarios have not been analysed in depth. However, given that the cost of avoiding energy demand with efficiency investments in the ESW scenario is lower than the competing cost of supplying that demand, the total economic cost with the given level of renewable energy utilization would be lower for the ESW scenario (which would achieve a 66 per cent reduction of carbon-equivalent emissions) than for the WEC:M scenario (which would result in a 10 per cent increase in emissions).

Global change in greenhouse gas emissions, year 2020



Note: Original scenario refers to emissions calculated using primary fuel consumption data as reported in the original WEC and ESW scenarios for 2020. The 2000 and 2020 accessible potentials refer to the total renewable energy supply potentials presented in tables 6 and 8 respectively, applied to the original WEC and ESW scenarios for 2020. The accessible supply potentials are applied towards reducing coal, oil and natural gas consumption in each scenario using the weighted average of each fossil fuel's contribution to 1985 world energy consumption as reported by WEC. Emissions factors: coal, 30.6 gram C_{eq}/megajoule (MJ); oil, 24.6 gram C_{eq}/MJ; natural gas, 17.2 gram C_{eq}/MJ. A 20-year time horizon is assumed in calculating the radiative forcing of the scenario for the given gases. Applying the economic potential in table 8 for the year 2020 would cause the carbon-equivalent emissions in the ESW scenario to be 66 per cent less than those in 1985. This figure approximates the 60 per cent emissions reduction identified by the Intergovernmental Panel on Climate Change (IPCC) as necessary for stabilizing atmospheric concentrations of CO_2. The higher level of renewable energy supply would not, however, enable attainment of atmospheric CO_2 concentration stabilization if energy demand were to grow as depicted in the WEC:M scenario: 2020 carbon-equivalent emissions would be 10 per cent greater than in 1985.

188. Various case-studies of emissions and economic impacts for industrialized and developing countries show the no-regrets aspect of using renewable energy sources in combination with high end-use efficiencies. The Second World Climate Conference concluded that even for the very near term, "technically feasible and cost-effective opportunities exist to reduce CO_2 emissions in all countries. Such opportunities ... are sufficient to allow many industrialized countries to stabilize CO_2 emissions from the energy sector and to reduce these emissions by at least 20 per cent by 2005 ... As additional measures to achieve further cost-effective reductions are identified and implemented, even greater decreases in emissions would be achieved in the following decades". 61/

3. Development and employment generation

189. Expanding the use of renewable energy sources in rural areas of developing countries can enhance the development process more rapidly and at a lower cost than comparable efforts with non-renewable sources. The following three examples illustrate this point. First, implementation of small-scale (for example, village-scale) power systems can make domestic, agro-industrial and other energy services available far sooner than would be the case if electricity from large central-station plants were to be transmitted over long distances. Second, other amenities (hot water, for example) can be made more widely available faster with renewable approaches (solar domestic hot water systems) than with fossil-fuel-based systems, such as natural gas pipelines and associated end-use heating systems. Lastly, solar driers for crops can help avoid post-harvest losses common to traditional natural open-air drying practices.

190. The construction, operation and maintenance of renewable energy systems can provide sizeable employment opportunities, especially in the rural context. Moreover, because operations and maintenance represent a larger fraction of their total costs, renewable energy supply technologies are inherently more effective at generating employment than fossil-fuel-based supply technologies. Opportunities for domestic manufacturing of the components of renewable energy systems bring double benefits of (a) increased employment and (b) reduced foreign debt.

191. The case of the Brazilian ethanol fuels programme provides an example of the employment-generation benefits of renewable energy systems. In Brazil, ethanol production today provides approximately 700,000 jobs. 62/ Most other economic activities in Brazil require larger investments per job created, the average investment being at least twice that per job created in the ethanol agro-industry. Costs per job created in the petrochemical industry have been up to 20 times higher. The average wage earned by sugar cane laborers in Sao Paulo is higher than that of 80 per cent of those working in other agricultural sectors, cattle raising, forestry and fishing. In addition, the ethanol production industry has a relatively low index of seasonal work.

4. Supply security and foreign debt reduction

192. Reducing fossil fuel consumption lessens energy supply vulnerability for oil-importing countries. Shifting toward domestic renewable energy investments can improve the balance of payments for both energy-importing and energy-exporting countries (by increasing fuel stocks available for export). Shifting towards domestic fuels offers the opportunity to diminish foreign debts owed by many developing countries.

D. Conclusions

193. If the world energy system were to develop in a direction where an increasing fraction of energy supply came from renewable energy sources, the energy-related problems associated with environment, development, and security would be considerably reduced. To make such problem reduction possible within the next several decades, the energy system must become increasingly more energy-efficient. However, the potential of economically efficient measures is not large enough for such a strategy to be sufficient. A combination of energy efficiency and renewable energy sources is required. Energy services will be significantly less costly in an energy system based on comparable investments in end-use efficiency and renewable supply than in one where only renewable energy is considered.

194. The contribution of renewable energy sources to global energy supply will be a function primarily of the degree of political commitment to renewable energy systems, both in creating fair-market conditions and in supporting technology research, development, demonstration and deployment.

Notes

1/ This high-level group of experts, designated in their personal capacity and selected on a geographical basis, was established in August 1990 by the Director-General for Development and International Economic Cooperation of the United Nations Secretariat. The Group is working under a request by the General Assembly that appeared in its resolution 45/208 of 21 December 1990. The Group's mandate is to prepare a comprehensive and analytical study on new and renewable sources of energy with a view to providing a significant contribution to the 1992 United Nations Conference on Environment and Development (UNCED), through the Preparatory Committee for the Conference to enable it to consider appropriate action, including funding and technology transfer, within its area of competence and within existing financial resources, not excluding voluntary contributions.

The members of the Group, chaired by Professor Thomas B. Johansson (Sweden), are listed in annex II of the present report.

UNSEGED has held meetings in New York, Sophia Antipolis (France), Rome, Snekkersten (Denmark), Munich and Oslo. Its work has been supported in cash and in kind by the Governments of Austria, Canada, Denmark, France, Germany, Italy, the Netherlands, Norway and Sweden. In support of UNSEGED's work, the Government of Denmark organized a conference (see Conference Proceedings: Global Collaboration on a Sustainable Energy Development, N. I. Meyer and P. S. Nielsen, eds. [Technical University of Denmark, April 1991]) and the Government of Norway, a meeting entitled "Symposium on Hydropower: Its Role in an Environmentally Sensitive World". The reports from these meetings are available from the respective Governments.

The Government of France has supported the Group's work through an evaluation of the accessible potential of renewbale energy sources (see Dessus and others, "Renewable energies: actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche, No. 1 (January 1992)). A scientific state-of-the-art review of technologies to utilize renewable sources of energy has been prepared for the United Nations in support of the work of UNSEGED and published separately (Fuels and Electricity from Renewable Sources of Energy, Johansson and others, eds. [Washington, D.C., Island Press, 1992]).

2/ Report of the United Nations Conference on New and Renewable Sources of Energy, Nairobi, 10-21 August 1981 (United Nations publication, Sales No. E.81.I.24), chap. I, sect. A.

3/ Defined for the purposes of the United Nations Conference on New and Renewable Sources of Energy to include solar, geothermal and wind power, tidal power, wave power and thermal gradient of the sea, biomass conversion, fuelwood, charcoal, peat, energy from draught animals, oil shale, tar sands and hydropower. See Report of the United Nations Conference on New and Renewable Sources of Energy, Nairobi, 10-21 August 1981 (United Nations publication, Sales No. E.81.I.24), introduction.

Notes (continued)

4/ Financial requirements for supporting actions and pre-investment activities for the development and utilization of new and renewable sources of energy in developing countries during the 1980s: joint study by the World Bank and the United Nations Development Programme (A/AC.215/4). The study was submitted, upon the request of the General Assembly in section VII of its resolution of 36/193 of 17 December 1981, to the Interim Committee on New and Renewable Sources of Energy and considered at its meeting of 7-18 June 1982 in Rome.

5/ Proposals for action-oriented plans and programmes for carrying out the Nairobi Programme of Action: report of the Administrative Committee on Coordination (A/AC.215/5). The report was prepared by the Administrative Committee on Coordination (ACC) Ad Hoc Working Group on Inter-agency Follow-up to the Nairobi Programme of Action, in response to the request of the General Assembly in section IV of its resolution 36/193 of 17 December 1981.

6/ Mobilization of financial resources and inter-agency coordination for the development and utilization of new and renewable sources of energy: report of the Secretary-General (A/AC.218/16), 1 February 1988.

7/ Progress achieved in resource mobilization, including consultative meetings, and inter-agency coordination: report of the Secretary-General (A/AC.218/1990/8).

8/ Organisation for Economic Cooperation and Development (OECD), Energy Policies of IEA Countries, 1990 Review (Paris, 1991).

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10/ Project proposals of entities within the United Nations system and the status of their implementation: report of the Secretary-General (A/AC.218/1990/9).

11/ Presently available statistics are inadequate for providing a precise estimate. A value for 1985 of 14 per cent was reported in Implementation of resolution 2 (III) of the Committee on the Development and Utilization of New and Renewable Sources of Energy at its third session: report of the Secretary-General (A/AC.218/15). In World Energy Horizons: 2000-2020. Fourteenth Congress of the World Energy Conference (Paris, Editions Technip, 1989), a value of 17.5 per cent was given. David Hall and others suggest that, in general, estimates of non-commercial use of biomass in developing countries are low. (See D. Hall and others, "Biomass for Energy: Future Supply Prospects", in Fuels and Electricity from Renewable Sources of Energy, T. B. Johansson, eds., [Washington, D.C., Island Press, 1992 (in press)].)

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14/ J. Goldemberg and others, Energy for a Sustainable World, (New Delhi, Wiley Eastern Limited, 1988).

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17/ Intergovernmental Panel on Climate Change, Working Group I, Scientific Assessment of Climate Change (Geneva, World Meteorological Organization, June 1990).

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27/ The list of new and renewable energy sources promoted by the United Nations Conference on New and Renewable Sources of Energy included oil shale, tar sands and peat. Those energy sources, however, present environmental problems similar to, or worse than, those connected with fossil fuels. In particular, their use results in CO_2 emissions. Consequently, they have not been considered in the present report.

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Annex II

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